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ORIGINAL

SAFETY AND HEALTH IN CONFINED WORKSPACES

—FOR THE CONSTRUCTION INDUSTRY—

A TRAINING RESOURCE MANUAL

COMPLETED

216

IES 17/16

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PREPUBLICATION COPY

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Public Health Service

Centers for Disease Control

National Institute for Occupational Safety and Health

Division of Training and Manpower Development

August 1984

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PREFACE

The purpose of this Training Resource Manual is to provide contractors and others in the construction industry with an overall understanding of the safety and health hazards associated with confined workspaces and the safeguards required to eliminate or reduce these hazards to acceptable levels; to provide information for use by those responsible for establishing or updating organizational policies and procedures for worker safety and health in confined workspaces; and to enable contractors and others to incorporate this information into in-house training programs for supervisors, foremen, members of the crafts, and those assigned to monitor safety and health conditions in confined workspaces.

The user of this manual is cautioned that each unit is written to be self-contained. For this reason, certain information may appear in more than one unit in the manual. This was done purposely to eliminate the possibility of essential information being lost if units are selected for use in other than their sequence in this manual.

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UNIT 1
INTRODUCTION TO THE NIOSH
CONFINED WORKSPACE TRAINING RESOURCE MANUAL

THE ISSUE

Fatalities and injuries constantly occur among construction workers who, during the course of their jobs, are required to enter confined workspaces. In some circumstances, these workers are exposed to multiple hazards, any of which may cause bodily injury, illness, or death. Newspaper and magazine articles abound with stories of workers injured and killed from a variety of atmospheric factors and physical agents, in spite of rules and regulations designed to eliminate or at least reduce confined workspace accidents.

An estimation of the number of workers potentially exposed to confined workspaces would be difficult to produce. Without such data, it is also not possible to guess with any accuracy at how many confined workspace-related injuries involve the construction industry. However, based on the total working population included in construction Standard Industrial Classification (SIC) codes, and a rough estimate of the percentage of workers in each category who may work in confined spaces at some time during the course of their work, it may be estimated that thousands of workers in a variety of crafts may be exposed to hazards in confined spaces each year.

Many fatalities occur each year when workers must enter and work in a confined workspace; but due to current data collection methods, an estimate of the injuries and deaths that do occur would very likely be inaccurate. Also, since there is no specific Standard Industrial Classification where these injuries and deaths are recorded for confined workspaces, they are recorded in several different categories, thereby giving the appearance of a limited exposure to the hazard.

Although most recorded fatalities and injuries sustained as the result of working in confined workspaces are associated with toxic, explosive, or oxygen-deficient atmospheres, many that are involved with or influenced by energy sources, such as steam, electricity, mechanical equipment, and

other factors such as small internal dimensions, go unreported. If all injuries and exposures sustained by construction workers in confined workspaces were reported, the statistics might be significantly higher.

An analysis of accidents involving workers in confined workspaces indicates that primary casual factors are failure of site supervision to study the potential hazards and to provide an appropriate safety and health program, failure of supervisors to follow standard operating procedures and enforce regulations, and failure of workers to recognize and take appropriate action to avoid the effects of the hazards present.

Safety and health hazards posed by a variety of toxic and explosive materials, oxygen-deficient atmospheres, and physical factors in confined workspaces are frequently insidious in nature and of extremely serious magnitude. Insidious hazards, whose effects are not manifested right away, are particularly threatening. Any damage that they cause to the worker's system can remain hidden for a long time, showing themselves suddenly when the effects have progressed so far as to be irreversible, possibly fatal. The potential for these and other types of hazards exists at many locations throughout the construction jobsite.

The mission of this manual is to eliminate or significantly reduce hazards in confined spaces on the construction jobsite, providing essential information on safety precautions to workers and management.

This training and educational manual is not all-inclusive and does not necessarily concern itself with all conceivable operations and conditions that may be encountered in work in confined workspaces. Instead, it is designed to develop an overall understanding of the problems encountered in confined workspaces and the solutions required to control them, so that the trainee will be able to apply the principles and concepts to a wide variety of circumstances on the construction jobsite involving confined workspaces.

THE NIOSH CONFINED WORKSPACE MANUAL

NIOSH believes that the solution to the many problems associated with confined workspaces involves a program of hazard recognition, hazard evaluation, and hazard control. Consistent with this philosophy, NIOSH has developed this training and educational program to stress the recognition of hazards associated with confined workspaces, and to provide information on such related topics as atmospheric testing and analysis of results, ventilation requirements, and personal protective equipment, to name just a few. It is the intent of NIOSH to reach management, supervision and labor in the construction industry with the purpose of increasing their ability to:

1. Recognize and evaluate a potentially hazardous confined workspace;
2. Understand the overall work process and environment to avoid the insidious hazards or latent dangers not readily apparent without close examination;
3. Understand the hazards associated with dangerous atmospheric contaminants;
4. Test the atmosphere in confined workspaces for contaminants and oxygen deficiency;
5. Use personal protective and safety equipment properly and monitor the confined workspace during work operations;
6. Establish effective communication systems;
7. Develop proficiency to assist in emergency entry and exit operations, and in the use of rescue, evacuation, and extrication equipment.

This NIOSH manual is consistent with OSHA regulations requiring the instruction of all employees who must enter a confined workspace. Instruction is to include the nature of the hazards involved, the necessary precautions to be taken, and the use of protective and emergency equipment required as per 29 CFR 1926.21 (b)(6).

NIOSH INTENT

The NIOSH intent for this program is to equip employees and employers with the information necessary to identify and take appropriate action for safeguarding operations in all confined workspaces encountered on the jobsite.

At the conclusion of the training program, the trainee should be able to:

1. Evaluate a workspace to determine whether it is safe to enter or to identify existing and potential hazards;
2. Determine that the proper administrative or

engineering controls or personal protective and safety equipment are utilized to reduce the potential hazard to acceptable levels;

3. Monitor the workspace to assure that the work environment remains within safe limits;
4. Communicate instructions to those workers who are required to enter the workspace;
5. Be proficient in the use of emergency and rescue equipment.

In essence, the overall objective of this training material is to produce competent people who, by acquiring information about and experience with the construction process, are familiar with the job or task to be performed, with appropriate control technology, with hazards that may be encountered, and with applicable safety and health standards.

DEFINING THE PROBLEM

The first step in a systematic approach to identifying and controlling a hazardous confined workspace is evaluating the existing and potential hazards associated with such spaces.

Difficult to Describe All Confined

It is practically impossible to cover all the situations that may cause accidents in the confined workspace. It will be best here to describe basic accident causes and to identify the general terms that define the problems and hazards. Later units will describe the terms in more detail, will show how to apply them to actual situations, and will introduce methods for their control.

Accident Effects

Accidents associated with confined workspaces are harmful not only when measured in human terms (that is, fatalities, injuries, and illnesses), but also when measured in terms of their impact on the overall construction project. Along with human losses, accidents result in:

1. Damage to or loss of equipment;
2. Damage to structures;
3. Delay in schedules;
4. Administrative costs;
5. Litigation.

Accidents Are Caused

In each accident situation involving a confined workspace, the cause can be directly or indirectly attributed to human factors (worker acts and omissions or management error), situational factors (faulty methods or equipment), or environmental factors (conditions such as oxygen-deficient, toxic or explosive atmospheres).

CAUSE FACTOR ONE—

Human Factor Acts of Commission and Omission

By the human factor, we mean the person who, by his commission (what he does), or by his omission (what he fails to do) causes an accident. A worker or supervisor may cause an accident by commission, for example, when he lights a welding torch without determining whether the atmosphere is flammable. He may cause an accident by an act of omission when he fails to observe warning signals.

Unsafe Act

Each of these actions is generally described as an unsafe act; that is, a human action which departs from hazard control procedures or practices or causes unnecessary exposure of a person to a hazard or hazards. Major types of unsafe acts are:

1. Entering a confined workspace without assuring that the atmosphere has been tested safe;
2. Using electrical equipment without first determining whether the environment in the confined workspace is explosive;
3. Operating equipment at an unsafe speed or in any other improper way;
4. Removing safety devices or rendering them inoperative.

When Human Error May Not be an Unsafe Act

Whenever a worker is directly involved in an accident, it seems that his actions are automatically tagged "unsafe." While a great many accidents are the result of someone doing something that he is not supposed to do, knowing very well that he is not supposed to do it (unsafe act), there are other situations where the worker becomes the target for criticism when, although he was directly involved in the accident, other factors forced him into this involvement. The following example illustrates this point.

Suppose a worker makes a weld in an atmosphere charged with a flammable vapor. When he lights the torch, an explosion occurs, and the welder is seriously injured. Obviously, the worker is instrumental in causing the accident, and consequently many people would judge his action an unsafe act. But it's possible that, as more facts in the case are disclosed, it could become apparent that the blame cannot be placed solely on his shoulders.

In this instance, let's assume that a failure in the contractor's management system contributed to the

accident. First of all, the contractor may not have had the confined workspace tested for flammable materials and then continuously monitored during the welding process. Second, the contractor may not have made certain that the worker understood the hazards in the specific operation at hand, that of welding in an explosive atmosphere, as well as the importance of observing the readings on the monitoring equipment.

Reducing Human Error

Differentiating between worker error and management error is a very important first step in preventing accidents on the construction jobsite and will determine what actions the contractor and workers must take to reduce accident potential in confined workspaces.

There are five key factors which can reduce human error on the jobsite.

First, supervisors and workers must know the correct methods and procedures for working in confined workspaces.

Second, workers should be able to demonstrate proficiency in recognizing and controlling hazards encountered in confined workspaces before they are permitted to enter the space to work.

Third, a worker's physical characteristics and fitness must be taken into consideration as it affects his operations at the jobsite. For example, poor eyesight or high blood pressure can cause a worker to make a faulty judgment or become dizzy at a crucial moment, making him a high risk for certain operations.

Fourth, supervisors and workers should maintain a high and continuous regard for their own and their fellow-workers' safety and health. If they are constantly aware and always alert to potentially dangerous situations in the confined workspaces, and if they take corrective action and encourage others to do the same, then great progress will be made in making the confined workspace a safe place in which to work.

The fifth factor in reducing human error is proper supervision. The supervisor in charge must be constantly aware of the level of skill each worker has acquired working with every piece of equipment and every tool in confined workspaces, and must adjust the supervision of each worker accordingly. Furthermore, when the supervisor lets it be known that he will accept nothing less than safe work practices and as safe an operation as possible, he establishes an important principle which shapes

worker's attitudes and actions, not only for a particular job, but for all jobs on which they will work.

CAUSE FACTOR TWO—

Situational Factors

The situational factor is another major cause of accidents in confined workspaces. Situational factors are those operations, tools, equipment, and/or materials which contribute to accident situations. Examples are:

1. Unguarded, poorly maintained, and defective equipment;
2. Electrical tools, lights, or other equipment that can cause shock if not properly grounded with an approved grounding system or with a ground-fault circuit interruptor;
3. Equipment without adequate warning signals;
4. Poorly arranged equipment that creates congestion hazards;
5. Equipment located in positions that can expose more workers to a potential hazard than is necessary.

Causes of situational problems that can produce accidents in the confined workspace are problems in design, such as a boiler within a vault (a confined space within a confined space); poor, substandard construction (such as a ladder built with defective lumber or with a variation in the space of its rungs); and small internal dimensions of the confined space, necessitating work in close proximity to electrical lines.

CAUSE FACTOR THREE—

Environmental Factors

The third factor in accident causation is the environmental factor—the way in which the confined workspace directly or indirectly can cause or contribute to accident situations. Environmental factors fall into three broad categories: physical, chemical, and biological.

Physical

Noise, vibration, illumination, heat, and cold are physical factors that have the capacity directly or indirectly to influence or cause accidents.

Chemical

In this category are toxic fumes, vapors, mists, smokes, and dust. In addition to causing illnesses, these elements often impair a worker's skill, reactions, judgment, or concentration. For example, a worker who has been exposed to the narcotic ef-

fect of some solvent vapors may experience an alteration of his judgment and move his hand too close to the cutting blade of a portable saw.

Biological

This category affects workers in some circumstances. Biological factors are those which are capable of making a person ill from contact with bacteria and microorganisms. These agents are found in waste systems and sewage facilities.

SOURCES OF SITUATIONAL AND ENVIRONMENTAL HAZARDS

Situational and environmental hazards enter the construction jobsite from many sources. The primary contributors are:

1. Those responsible for assuring that the jobsite is safe;
2. Those responsible for tool, equipment, and machinery placement and for providing adequate machine guards;
3. Those responsible for monitoring the confined workspace during work activity.

Workers as a Source

Workers may also contribute to situationally and environmentally caused hazards by disregarding safety rules and regulations, by making safety devices inoperative, by using equipment and tools incorrectly, by using defective tools rather than taking the time to secure serviceable ones, by failing to use exhaust fans when required, by using toxic substances in unventilated areas, and by failing to use protective equipment.

HAZARD DEFINITION

So far, we have discussed examples of accident causes. From this point on, accident causes will be referred to as *hazards*. A workable definition of *hazard* is:

any existing or potential condition in the workplace which, by itself or by interacting with other variables, can result in the unwanted effects of property damage, illnesses, injuries, deaths, and other losses (Firenze, 1978).

This definition carries with it two significant points. First, a condition does not have to exist at the moment to be classified as a hazard. When the total hazard situation is evaluated, potentially hazardous conditions must be considered. Second, hazards may not result from independent failure of workplace components but from one workplace component acting upon or influencing another. For

instance, what would happen if, while welding was being done, methane were to seep into the confined workspace? Or, what would happen if materials stored on the ground above the confined workspace were to fall in?

Though a hazard is a hazard no matter what its origin, hazards are generally grouped in two categories: safety hazards, which can cause injuries, and health hazards, which can cause illnesses.

Safety Hazard

A safety hazard usually results in trauma. It evolves from a situation in which workers may be injured or killed because of electrical, thermal, and mechanical conditions (such as faulty electrical wiring on tools and equipment, or unguarded gears or blades on equipment).

Health Hazard

A health hazard is a condition that has the potential to cause illness. Examples of health hazards are high noise levels, oxygen-deficient atmospheres, or toxic fumes, mists or vapors.

Combination Safety and Health Hazard

A single condition, substance, or material can be classified as both a safety and a health hazard at the same time. For example, toxic vapor from a flammable solvent can cause lung irritation—or perhaps more advanced forms of illness if inhaled over long periods of time. If this substance is used in a confined workspace without adequate ventilation, or if it comes in contact with an open flame, it may ignite and explode, causing severe injury or death to workers and extensive damage to property. In this case, the solvent vapor, normally considered a health hazard, is also a safety hazard.

Types of Hazards Encountered in Confined Workspaces

Some types of hazards encountered in confined workspaces are:

1. Toxic substances such as unhealthful or fatal concentrations;
2. Flammable or combustible gases, vapors, or dusts with potential for fire or explosion;
3. Oxygen deficiency, resulting from oxidation of metals, combustion, or displacement by inert gases;
4. Exposure to physical agents (noise, ionizing radiation, extreme temperature);
5. Electrical shock from portable lights, tools, or associated electrical equipment;

6. Mechanical equipment that may be defective, inadvertently or incorrectly operated, or not properly de-activated;
7. Direct contact with corrosives or dermatitis-producing chemicals (acids, caustics, cutting oils);
8. Physical hazards, such as slipping and falling, or falling objects.

Some hazards associated with confined workspaces can be generalized across the industries; others cannot. For instance, hazards associated with boiler entry are similar to a great extent throughout industry. However, in the construction industry, confined workspaces are encountered that are unique. Complex configurations of pipe assemblies and ductwork, coupled with manholes, diesel vaults, and so forth, create confined workspaces that are potentially hazardous. In some instances, construction workers must work in confined workspaces that are themselves contained within confined spaces.

A General Misunderstanding

An issue of significance when dealing with confined workspaces in the construction industry is that, traditionally, a hazardous confined workspace has been conceived only as one that possesses a hazardous atmosphere (e.g., oxygen-deficient, combustible/explosive, toxic, etc.). Thus, many confined workspaces with the potential to cause death and injury from other factors such as energy sources (steam, electricity, etc.), mechanical equipment/machinery within the workspace, materials possibly falling into the workspace, or height from which a worker could fall, are often not considered.

Using a single criterion to sort confined workspaces from other workspaces on a jobsite has one major flaw: a great number of workspaces that should be classed as "confined" are overlooked. As a result, injuries and fatalities in the overlooked confined spaces are never recorded as occurring in a confined space. Thus, statistics are deficient in pointing up the full issue of fatalities and injuries associated with confined workspaces.

Up to this point the term *confined workspace* has been used to describe a broad array of situations. Because these situations vary from circumstance to circumstance, and because there is a general misunderstanding over what constitutes a hazardous confined workspace, we will define the term here and use this definition throughout this training manual.

Hazardous Confined Workspace

A hazardous confined workspace may be defined as a workspace normally enclosed by design (for example, a storage tank or shaft). Or, it may be defined as a workspace that is confined because of its unique configuration in design or construction (for example, a pipe run or ventilation duct).

Characteristics of a Hazardous Confined Workspace

A hazardous confined workspace possesses one or more of the following characteristics:

1. A limited access, hindering emergency rescue;
2. An existing or potentially hazardous atmosphere (for example, oxygen-deficient, combustible/explosive, toxic, noisy, radioactive, hot) which is:
 - a. inherent in the workspace (for example, methane gas seepage into a manhole), or
 - b. introduced into the workspace by
 - those performing operations within the confined workspace (for example, fumes from welding or argon from inerting operations), or
 - others in a work area remote to, but affecting, the environment within the confined workspace (for example, an ironworker creating welding fumes that enter a pipe assembly where pipefitters are working);
3. An energy source (steam, electricity, etc.) controlled at a point outside the workplace;
4. Small internal dimensions that require workers to be in close proximity to the source of the hazard;
5. Mechanical equipment/machinery within the workspace that has its power controlled at a point outside the workspace;
6. Sufficient height to be hazardous should a worker fall;
7. A situation where workers within the space

cannot be observed by workers outside the workspace;

8. Possibility of materials and equipment falling into the confined workspace;
9. Unstable structural integrity of the walls of the workspace.

Dangers in Confined Workspaces

The possible hazards associated with confined workspaces may be grouped into four categories: hazards connected with oxygen deficiency, with explosion, with toxic chemicals and physical agents, or with energy sources that can cause serious injuries and fatalities.

Workers in any particular confined space may encounter any combination of these hazards. For example, a worker in a confined space that formerly contained leaded gasoline would need to take protective measures against:

1. Intoxication from the gasoline vapors;
2. Asphyxiation caused by displacement of oxygen by the gasoline vapor;
3. Explosion caused by a flammable mixture of gasoline vapor;
4. Poisoning from skin contact with an inhalation of organic lead compounds;
5. Fire from pyrophoric (spontaneous ignition) materials such as iron sulfides.

CONCLUSION

This unit provides a foundation of information on which specific hazards may be evaluated. It also previews the general hazards found in the confined workspace. Later units will discuss individual hazards in greater detail.

Reference

1. Firenze, Robert J. *Safety and Health for Industrial/Vocational Education* (Cincinnati: The National Institute for Occupational Safety and Health), July 1981. Unit I, "Impact of Accidents on Industrial Vocational Education Shop Programs."

Instruction Key—Unit 1

Introduction to the NIOSH Confined Workspace Training Program

Terms

1. Insidious hazards—those whose effects may remain hidden for long periods of time, manifesting themselves suddenly when they have progressed so far as to be irreversible, possibly fatal.
2. Human factors—worker or management errors.
3. Situational factors—faulty methods or equipment.
4. Environmental factors—conditions such as oxygen deficiency, toxic atmosphere, or noise.
5. Hazard—any existing or potential condition in the workspace which, by itself or by interacting with other variables, can result in the unwanted effects of property damage, illnesses, injuries, deaths and other losses.
6. Safety hazard—potential for causing injury.
7. Health hazard—potential for causing illness.
8. Combination safety and health hazard.

Points for Discussion

1. The issue
Statistics are hard to come by, but a general breakdown can be made as to the types of injuries that occur in confined workspaces, their approximate frequency and primary causes of confined workspace accidents.
2. The NIOSH Confined Workspace Manual
Background—intent
3. Types of hazards encountered in confined workspaces
Safety
Health
Combination

4. General misunderstanding

A single criterion used to sort confined workspaces from other workspaces on a job-site will result in many true confined spaces being overlooked for evaluation and recording.

5. Dangers in confined spaces

Questions

1. Under what circumstances may human error be attributable to a factor other than an unsafe act?
2. Name the three types of environmental factors.
3. Give an example of a combination safety and health hazard and explain your choice.
4. What are the four general hazards associated with confined workspaces?

Answers

1. When the error occurs in the management system, such as in incomplete safety instructions or faulty supervision.
2. Physical, chemical and biological.
3. A flammable vapor from a solvent may cause lung irritation or some form of illness and may also be volatile, presenting the risk of fire or explosion if used without adequate ventilation.
4. The four groups of hazards are:
 - a. Oxygen deficiency
 - b. Explosion
 - c. Toxic chemicals and physical agents
 - d. Energy sources that can cause serious injuries and fatalities.

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UNIT 2

RESPONSIBILITIES FOR SAFETY AND HEALTH IN CONFINED WORKSPACES

Owners, construction managers, contractors, supervisors, and workers must understand the importance of a systematic approach to identifying hazardous or potentially hazardous confined workspaces, of evaluating the existing and potential hazards associated with these spaces, of instituting effective controls, and of monitoring work activities in the space until work is completed.

ACCIDENT REDUCTION—A TEAM APPROACH

To be effective, a hazard control program for work in confined workspaces requires the active cooperation of both management and labor. The contractor plays a significant role in directing overall policy setting. The foremen and supervisors, through their enforcement of these policies, are also important links in the total effort. So, too, are the workers who are in prime positions to assess conditions within the confined spaces and to observe the proper safety and health practices.

The Contractor

The contractor is responsible for establishing and implementing a comprehensive confined workspace hazard control program as an integral part of the overall jobsite safety and health program. In so doing, the contractor will enforce the mandatory requirements of OSHA as they relate to work in confined workspaces, guided by all information intended to assure the highest degree of protection to workers that is practical in an operational setting. The contractor is the one to initiate procedures and directives, and to require inspections necessary to assure compliance with the standards and regulations. It is also his responsibility to require that personnel of other contractors and subcontractors working in conjunction with his operation conduct their work in accordance with prescribed hazard control provisions.

As well, the contractor is responsible for determining that any confined workspace to be entered has a suitable means of egress from all accessible

parts of the confined space, and that it is safe for entry.

When gases, vapors, mists, fumes, etc., that are likely to be dangerous are present in any of the confined workspaces, or when there is a deficiency of oxygen or a temperature that is likely to be dangerous to a person working in the confined workspace, the contractor should forbid entry into the workspace until:

1. Every practicable step has been taken to purge the space of such contaminants;
2. Effective steps have been taken to prevent exacerbation of the conditions within the space;
3. The confined workspace has been tested and found safe for entry without the use of a breathing apparatus;
4. Adequate ventilation has been provided.

When testing determines that a confined workspace is safe for entry for a specified time, but the space may thereafter become unsafe unless a person is using a suitable respirator, the contractor should ensure that continuous monitoring of the workspace is provided, and that any person who enters the space without using a suitable respirator leaves the space at the end of the specified time. The contractor should then make certain that no worker re-enters or remains in the space unless he can be properly provided with a suitable respirator, safety harness, and alarm. In addition, a worker adequately trained in emergency procedures should be available.

Supervisory Personnel

All supervisors should be familiar with the procedures and methods of the confined workspace hazard control program as they relate to personnel or operations under their supervision. They will survey each operation and determine whether a confined workspace exists. Upon determining that a confined workspace does exist, they must identify all recognizable hazards and communicate these hazards to the jobsite safety department.

Supervisors should explain to all employees under their immediate supervision the nature of the hazards associated with the operations and the precautions necessary to control such hazards.

They should also supervise the atmospheric monitoring of all confined workspaces under their immediate supervision to assure the safety and health of all personnel.

And finally, supervisors should report unsafe conditions or procedures and, where warranted by the severity of such conditions, cease all operations until corrective action has been effected.

Workers

All workers engaged in work in confined workspaces are responsible, once they have been trained, for fully understanding and strictly observing the safety and health standards, regulations, and procedures applicable to such work.

It is the responsibility of the workers to report to their immediate supervisor any condition, procedure, or equipment that they recognize as unsafe.

They should warn other workers of any failure to observe proper procedures or precautions or of any hazard present.

Workers should also report to their supervisor any injury or evidence of impaired health occurring in the course of work or potentially affecting the safe performance of duties.

In addition, they should report to their supervisor the malfunction or suspected malfunction of any test or monitoring instrument.

No worker should ever enter a confined workspace which does not have a safe work permit.

SPECIAL DUTIES

Confined Workspace Monitor

On some jobsites, it may be beneficial to assign trained persons to the duties of confined workspace monitoring. These monitors would be responsible for determining whether confined workspaces are potentially hazardous, whether adequate protective measures have been instituted, and whether the potential atmospheric and physical hazards in the confined workspace are sufficiently under control and the workspace safe for entry. They should also be able to use detection and monitoring devices to evaluate the environment in the confined workspace, and should know emergency entry and exit procedures and procedures for the use of rescue equipment and first-aid.

Members of Joint Safety and Health Committee

Where jobsite safety and health committees are organized, the members are responsible for assisting the contractor in identifying and understanding the control of hazards associated with confined workspaces, understanding the use and results produced by detection and monitoring equipment and instruments, assessing the effectiveness of hazard controls used in conjunction with identified hazards in confined workspaces, and communicating these issues to the contractor.

In this unit, we have examined general responsibilities of each group involved in confined workspace activities. The next unit, "Essential Processes in a Confined Workspace Hazard Control Program," details the responsibilities of the contractor.

Instruction Key—Unit 2

Responsibilities for Safety and Health in Confined Workspaces

Points for Discussion

1. Cooperation—the key to a successful confined workspace safety and health program
2. Responsibilities
 - The Contractor
 - The Supervisor
 - The Worker
3. Special duties
 - Confined workspace monitors
 - Joint safety and health committee

Questions

1. In broad terms, what is the major difference between the responsibilities of the contractor, those of the supervisor, and those of the worker?
2. If a workspace has been tested as safe, but the possibility exists that it may become unsafe

while work is still underway, what precautionary measures should the contractor take?

3. What item *must* be filled out and signed by the supervisor and displayed on the workspace before any worker may enter?

Answers

1. The contractor's duties are largely administrative; the supervisor's duties emphasize enforcement; and the worker's duties require adherence to set procedures.
2. He should make certain that workers leave the space within the specified safe time and that no one re-enters or remains in the space without the proper equipment and without another worker to assist from outside the space.
3. An entry permit is always required for entry.

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UNIT 3

ESSENTIAL PROCESSES IN A CONFINED WORKSPACE HAZARD CONTROL PROGRAM

A well-organized confined workspace safety and health program should carry out the following processes (Firenze, 1978):

1. Recognition and evaluation of potential hazards;
2. Administrative decision-making;
3. Establishment of corrective and preventive measures;
4. Inspection and monitoring;
5. Evaluation of program effectiveness.

PROCESS ONE: EVALUATE AND IDENTIFY WORKPLACE HAZARDS

The first process in a comprehensive confined workspace hazard control program is to identify and evaluate hazards located in the workspace. These hazards are associated with a variety of physical and chemical agents and a variety of energy sources which may cause bodily injury and fatality. The purpose of this process is to acquire information about what specific hazards exist, to rank discovered hazards according to their potential destructive effect, and to estimate the probability of the hazard resulting in an accident situation.

Here the contractor is responsible for ascertaining, on an ongoing basis, confined workspaces that already exist as well as those that will be created as a direct result of the construction process.

The recognition process will consider the hazards of oxygen deficiency, explosion, and exposure to energy sources that are capable of causing serious injuries and fatalities. In addition, to avoid the insidious or unexpected hazard, a total overview must be obtained of the jobsite, the process, and the proposed confined space operations. This will require a detailed list of the hazards in the space itself (the chemicals and materials previously occupying or forming the space), the operations to be performed (welding, painting, solvent cleaning, etc.), and the adjacent areas or operations which may contribute toxic chemicals or other hazards (pressurized tanks, sewers, inert gas lines, cryogenic environment, etc.).

Locating Hazards Associated With Confined Workspaces

The contractor, with the help of his supervisors, safety personnel, workers and perhaps a safety committee, should be prepared to define all existing and potential confined workspaces where various crafts and supervisory personnel will be working.

An early review of the project planning system will be help to identify some of the confined workspaces.

Regular inspections will help to identify other spaces which may have emerged during the construction process.

Ranking Hazards According to Potential Destructive Consequences

The second aspect of the first process deals with ranking discovered hazards according to their potential consequences. When hazards are ranked according to established criteria for hazard evaluation, it is possible to specify which hazardous conditions warrant immediate action, which can take secondary priority, and which can be addressed in the future. Without such a system, there can be no consistent guide for corrective action. Even worse, if time is not taken to rank hazards on a "worst first" basis, efforts and resources could be wasted solving problems of lower consequence while those with greater destructive potential are overlooked. The following scheme is suggested for hazard evaluation.

HAZARD SEVERITY

- | | |
|------------------------|--|
| 1. Catastrophic Hazard | The hazard is capable of causing death (possibly multiple deaths), widespread occupational illnesses and loss of jobsite facilities. |
| 2. Critical Hazard | The hazard can result in death, injury, serious illness and property and equipment damage if not corrected as soon as possible. |

- | | |
|----------------------|---|
| 3. Marginal Hazard | The hazard can cause injury, illness and equipment damage, but the injury, illness and equipment damage would not be serious. |
| 4. Negligible Hazard | The hazard will not result in a serious injury or illness. The potential for the hazard causing damage beyond a minor first aid case is extremely remote. |

HAZARD PROBABILITY

- A—Probable
- B—Reasonably Probable
- C—Remote
- D—Extremely Remote

When the hazards have been ranked according to both sets of criteria, it is easy to determine where action is mandated. A hazard rating of 1A will demand corrective action before a hazard with a rating of 2B. For example, an oxygen-deficient or flammable atmosphere in a confined workspace must be attended to before slippery surfaces. Slippery-surface hazards, along with similar hazards, wouldn't be overlooked. This and similar hazards would simply be attended to after the grave hazards are abated.

PROCESS TWO: MANAGEMENT DECISION-MAKING

The second process involves the contractor's ability to make intelligent, informed decisions concerning hazard control by assessing alternative solutions to the problems identified. Such alternatives will include recommendations for ventilation, monitoring, specific safe work procedures, emergency measures, etc. Essentially, the contractor will place a variety of alternative solutions into four broad categories:

1. Modify methods and procedures;
2. Introduce a system of testing and evaluation;
3. Provide hazard controls, including ventilation, machine guards, controls to guard against electrical shock, personal protective equipment, etc.;
4. Establish emergency procedures and methods.

Format for Decision-Making

Table 3.1, Record of Safety and Health Deficiencies in Confined Workspaces, illustrates one approach for recording and displaying hazard information for decision-making.

The second process, then, enables contractors to make informed decisions in order to upgrade their

operations and methods associated with work in confined workspaces. This process ensures that action is taken to provide a safe and healthy workspace in which workers may perform their duties.

PROCESS THREE: INSTITUTING PREVENTIVE AND CORRECTIVE MEASURES

After hazards have been identified and evaluated, and information for intelligent decisions provided, the next process involves the actual installation of control measures. Here the contractor must decide either how to eliminate the hazards or how to reduce them in such a way that they can be adequately controlled with proper safety measures. Before implementation of controls takes place, it is essential that the contractor understand the alternatives to controlling hazards. Figure 3.1 illustrates the three major areas where we can either eliminate or control hazardous conditions (Firenze, 1978).



Figure 3.1 The three points for hazard control.

The first and perhaps best control alternative is to attack a hazard at its source. One way is to substitute a less harmful agent for the one causing the problem. For example, if it is found that a flammable toxic solvent is being used in a confined workspace, the first step is to determine whether the hazardous substance can be exchanged for one which is nontoxic and nonflammable yet still able to do the job. Should the contractor determine that a nonhazardous solvent cannot be found or is impractical to use, then he must look for a less toxic, less flammable substance and employ additional safeguards such as adequate ventilation provided by a local exhaust system.

The second alternative is to control the path of the hazard by erecting a barricade between the hazard and the workers. Examples of such engineering controls are:

1. The local exhaust system previously mentioned which removes toxic vapors from the work area;

TABLE 3.1

RECORD OF SAFETY AND HEALTH DEFICIENCIES IN CONFINED WORKSPACES

Location _____

J. Smith, Safety Supervisor

Deficiency No.	Date Recorded	Description of Hazardous Condition	Specific Location	Identification of Acceptable Standard	Hazard Rating	
					Conseq.	Prob.
1	12/11/79	Unapproved Equipment Ground	Containment Area	OSHA: Subpart S National Electrical Code, Article 250; 4 S	1	A

Essential Processes in a Confined Workspace Hazard Control Program

2. Machine guards, which prevent a worker's body parts from making contact with hazardous parts of the machinery, such as a cutting surface;
3. Ground-fault circuit interruptors, which protect workers against electrical shock.

The third alternative is to direct control efforts at the receivers—the workers themselves. This alternative is generally accomplished by providing the worker with personal protective equipment. Protective equipment may be selected for use in three instances: when there is no immediately feasible way to control the hazard by more effective means; when the protective equipment is employed as a temporary measure, while more effective solutions are being sought; or when the protective equipment is employed as a secondary or back-up measure to insure greater worker protection.

There are, however, major shortcomings associated with the use of personal protective equipment.

First, nothing has been done to eliminate or reduce the hazard. For instance, even though a worker is equipped with a respirator for use in an oxygen-deficient atmosphere, the atmosphere itself is still hazardous. Should the worker be exposed to this atmosphere, he will be subjected to a severe and immediate hazard.

Second, if the protective equipment (glove, eye shield, respirator, etc.) fails for any reason, does not fit properly, or is not used properly, the worker is exposed to the full destructive effects of the hazard.

And, finally, the protective equipment may be cumbersome and may interfere with the worker's ability to work. This is an especially difficult problem when working in confined workspaces. Often, workspace is limited. The configuration of the space, coupled with obstructions in it, sometimes makes it very difficult for workers to accomplish their tasks while wearing certain types of protective equipment.

Therefore, protective equipment is a last-resort remedy. However, because of the nature of construction and the types of activities in which workers are often involved, personal protective devices may be the only viable alternative.

PROCESS FOUR: SAFETY AND HEALTH INSPECTIONS

The fourth process in the hazard control program deals with the inspection or monitoring of operations in the confined workspace in order to verify that conditions are safe. Monitoring enables the contractor to:

1. Provide assurance that hazard controls are working properly;
2. Determine that conditions have not changed to a degree that the hazard controls are unable to cope with the hazards;
3. Discover new hazards that have been created due to the nature of the confined workspace or the processes and operations being conducted in it.

PROCESS FIVE: EVALUATING THE PROGRAM

The fifth element in the program deals with evaluating the effectiveness of efforts to improve the overall quality of the confined workspace hazard control program. When contractors commit effort and resources to assure that workers are protected against hazards in confined workspaces, they should be able to determine that the program is doing the job.

Among the criteria which may assist the contractor in evaluating the success of his program are the number of worker injuries or exposures, the number of instances when hazardous atmospheres were identified and controlled, and the amount of equipment and tool damage.

This unit and the one preceding it have discussed the responsibilities associated with confined workspace safety and health programs. The next unit, "Anatomy of Confined Workspaces in Construction," provides criteria for identifying confined workspaces and their hazards on the construction site.

References

1. Firenze, Robert J., *The Process of Hazard Control* (Dubuque, Iowa: Kendall/Hunt Publishing Company, 1978).
2. Thomas, F.C. et al., "Guidelines for Work in Confined Spaces," *The Medical Bulletin*, Volume 40, Summer 1980.

Instruction Key—Unit 3

Essential Processes in a Confined Workspace Hazard Control Program

Terms

1. Hazard severity
 - a. Catastrophic
 - b. Critical
 - c. Marginal
 - d. Negligible
2. Hazard probability
 - a. Probable
 - b. Reasonably probable
 - c. Remote
 - d. Extremely remote
3. Hazard control alternatives
 - a. Substitution at the hazard source
 - b. Barricading along the hazard path
 - c. Protecting the hazard receiver

Points for Discussion

1. Process One: Evaluation and identification of workspace hazards
 - a. Locating specific hazards
 - Oxygen deficiency, explosion, toxic agents, energy sources
 - Hazards within the space, operations to be performed, and adjacent hazards or operations
 - Confined spaces arising during the construction process
 - b. Ranking discovered hazards
 - Hazard severity
 - Hazard probability
2. Process Two: Management decision-making
 - a. Ventilation, monitoring, safe work procedures
 - b. Four main types of control alternatives
 - Modify methods and procedures
 - Introduce system of testing and evaluation
 - Provide hazard controls
 - Establish emergency procedures
3. Process Three: Instituting preventive and corrective measures

a. Control alternatives

- At the source
- Along the path
- At the receiver

4. Process Four: Safety and health inspections
5. Process Five: Evaluating the program
 - a. The number of worker injuries or exposures
 - b. The number of instances where hazardous atmospheres are identified and controlled
 - c. The amount of tool and equipment damage

Questions

1. Name the five essential processes in a confined workspace safety and health program.
2. What is a catastrophic hazard?
3. Of the three hazard control alternatives, which is the best, and why?
4. What are the three major pitfalls associated with the use of personal protective equipment?

Answers

1. Recognition and evaluation of potential hazards; administrative decision-making; establishment of corrective and preventive measures; inspection and monitoring; and evaluation of program effectiveness.
2. A catastrophic hazard is capable of causing death (perhaps many deaths), widespread occupational illnesses and loss of jobsite facilities.
3. It is usually best to try to control a hazard at the source, where it originates. That way, the need for the other two alternatives, controlling the hazard along the path or at the receiver, will be greatly reduced if not eliminated.
4. First, it does nothing to reduce or eliminate the hazard. Second, it must be in perfect condition and properly used to assure full protection. And, finally, it may limit the worker's ability to perform certain tasks.

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UNIT 4

ANATOMY OF CONFINED WORKSPACES IN CONSTRUCTION

Throughout the construction jobsite, contractors and workers encounter both inherent and induced hazards within confined workspaces. We introduced hazards in Unit 1. At this point we will refine the term further.

INHERENT HAZARDS

Inherent hazards, such as electrical, thermal, chemical, mechanical, etc., are associated with specific types of equipment and the interactions among them. Examples include high voltage (shock or corona discharge and the resulting burns), radiation generated by equipment, defective design, omission of protective features (no provision for grounding non-current-carrying conductive parts), high or low temperatures, high noise levels, and high-pressure vessels and lines (rupturing with resultant release of fragments, fluids, gases, etc.).

Inherent hazards usually cannot be eliminated without degrading the system or equipment, or without making them inoperative. Therefore, emphasis must be placed on hazard control methods.

INDUCED HAZARDS

Induced hazards arise and are induced from a multitude of incorrect decisions and actions that occur during the actual construction process. Some examples are: omission of protective features, physical arrangements that may cause unintentional worker contact with electrical energy sources, oxygen-deficient atmospheres created at the bottom of pits or shafts, lack of safety factors in structural strength, and flammable atmospheres.

EXAMINATION OF TYPICAL CONFINED WORKSPACES

Following are typical examples of confined workspaces in construction which contain both inherent and induced hazards.

Vaults

A variety of vaults are found on the construction

jobsite. On various occasions, workers must enter these vaults to perform a number of functions. The restricted nature of vaults and their frequently below-grade location can create an assortment of safety and health problems.

Oxygen Deficient Atmosphere

One of the major problems confronting construction workers while working in vaults is the ever-present possibility of an oxygen-deficient atmosphere.

Explosive or Toxic Gases, Vapors, or Fumes

While working in an electrical vault, workers may be exposed to the build-up of explosive gases such as those used for heating (propane). Welding and soldering produce toxic fumes which are confined in the limited atmosphere.

Electrical Shock

Electrical shock is often encountered from power tools, line cords, etc. In many instances, such electrical shock results from the fact that the contractor has not provided an OSHA-approved grounding system or the protection afforded by ground-fault circuit interruptors or low-voltage systems.

Purging

In some instances, purging agents such as nitrogen and argon may enter the vault from areas adjacent to it. These agents may displace the oxygen in the vault to the extent that it will asphyxiate workers almost immediately.

Materials Falling In and On

A hazard normally considered a problem associated with confined workspaces is material or equipment which may fall into the vault or onto workers as they enter and leave the vault. Vibration could cause the materials on top of the vault to roll off and strike workers. If the manhole covers were removed, or if they were not installed in the first place, materials could fall into the vault, causing injury to the workers inside.

Condenser Pits

A common confined workspace found in the construction of nuclear power plants is the condenser pit. Because of their large size, they are often overlooked as potentially hazardous confined spaces. These below-grade areas create large containment areas for the accumulation of toxic fumes, gases, and so forth, or for the creation of oxygen-deficient atmospheres when purging with argon, freon, and other inert gases. Other hazards will be created by workers above dropping equipment, tools, and materials into the pit.

Manholes

Throughout the construction site, manholes are commonplace. As means of entry into and exit from vaults, tanks, pits, and so forth, manholes perform a necessary function. However, these confined workspaces may present serious hazards which could cause injuries and fatalities.

A variety of hazards are associated with manholes. To begin with, the manhole could be a dangerous trap into which the worker could fall. Often covers are removed and not replaced, or else they are not provided in the first place.

Pipe Assemblies

One of the most frequently unrecognized types of confined workspaces encountered throughout the construction site is the pipe assembly. Piping of sixteen to thirty-six inches in diameter is commonly used for a variety of purposes. For any number of reasons, workers will enter the pipe. Once inside, they are faced with potential oxygen-deficient atmospheres, often caused by purging with argon or another inert gas. Welding fumes generated by the worker in the pipe, or by other workers operating outside the pipe at either end, subject the worker to toxic atmospheres. The generally restricted dimensions of the pipe provide little room for the workers to move about and gain any degree of comfort while performing their tasks. Once inside the pipe, communication is extremely difficult. In situations where the pipe bends, communication and extrication become even more difficult.

Electrical shock is another problem to which the worker is exposed. Ungrounded tools and equipment or inadequate line cords are some of the causes. As well, heat within the pipe run may cause the worker to suffer heat prostration.

Ventilation Ducts

Ventilation ducts, like pipe runs, are very com-

mon at the construction site. These sheet metal enclosures create a complex network which moves heated and cooled air and exhaust fumes to desired locations in the plant. Ventilation ducts may require that workers enter them to cut out access holes, install essential parts of the duct, etc. Depending on where these ducts are located, oxygen deficiency could exist. They usually possess many bends, which create difficult entry and exit and which also make it difficult for workers inside the duct to communicate with those outside it. Electrical shock hazards and heat stress are other problems associated with work inside ventilation ducts.

Tanks

Tanks are another type of confined workspace commonly found in construction. They are used for a variety of purposes, including the storage of water, chemicals, etc.

Tanks require entry for cleaning and repairs. Ventilation is always a problem. Oxygen-deficient atmospheres, along with toxic and explosive atmospheres created by the substances stored in the tanks, present hazards to workers.

Heat, another problem in tanks, may cause heat prostration, particularly on a hot day. Since electrical line cords are often taken into the tank, the hazard of electrical shock is always present. The nature of the tank's structure often dictates that workers must climb ladders to reach high places on the walls of the tank.

Sumps

Sumps are commonplace. They are used as collection places for water and other liquids. Workers entering sumps may encounter an oxygen-deficient atmosphere. Also, because of the wet nature of the sump, electrical shock hazards are present when power tools are used inside. Sumps are often poorly illuminated. Inadequate lighting may create an accident situation.

Containment Cavities

These large below-grade areas are characterized by little or no air movement. Ventilation is always a problem. In addition, the possibility of oxygen deficiency exists. As well, welding and other gases may easily collect in these areas, creating toxic atmospheres. As these structures near completion, more confined spaces will exist as rooms are built off the existing structure.

Electrical Transformers

Electrical transformers are located on the jobsite.

They often contain a nitrogen purge or dry air. Before they are opened, they must be well vented by having air pumped in. Workers, particularly electricians and power plant operators, will enter these transformers through hatches on top for various work-related reasons. Testing for oxygen deficiency and for toxic atmospheres is mandatory.

Heat Sinks

These larger pit areas hold cooling water in the event that there is a problem with the pumps located at the water supply to the plant—normally a river or lake—which would prevent cooling water from reaching the reactor core.

When in the pits, workers are exposed to welding fumes and electrical hazards, particularly because water accumulates in the bottom of the sink.

Generally, it is difficult to communicate with workers in the heat sink, because the rebar in the walls of the structure deaden radio signals.

UNUSUAL CONDITIONS

Confined Workspace Within a Confined Workspace

By the very nature of construction, situations are created which illustrate one of the most hazardous confined workspaces of all—a confined workspace within a confined workspace. This situation appears as tanks within pits, pipe assemblies or vessels within pits, etc. In this situation, not only do the potential hazards associated with the outer confined workspace require testing, monitoring, and control, but those of the inner space also require similar procedures. Often, only the outer space is evaluated. When workers enter the inner space, they are faced with potentially hazardous conditions.

A good example of a confined workspace within

a confined workspace is a vessel with a nitrogen purge inside a filtering water access pit. Workers entering the pit and/or the vessel should do so only after both spaces have been evaluated and proper control measures established.

Hazards In One Workspace Entering Another Workspace

During an examination of confined workspaces in construction, one often encounters situations which are not always easy to evaluate or control. For instance, a room or area which classifies as a confined workspace may be relatively safe for work. However, access passages from other areas outside or adjacent to the room could, at some point, allow the transfer of hazardous agents into the "safe" one.

One such instance would be a pipe coming through a wall into a containment room. Welding fumes and other toxic materials generated in one room may easily travel through the pipe into another area, causing it to change from a safe to an unsafe workplace. A serious problem with a situation such as this is that workers working in the "safe" area are not aware of the hazards leaking into their area. Thus, they are not prepared to take action to avoid or control it.

CONCLUSION

In this unit we have defined inherent and induced hazards in confined spaces. We have examined typical confined spaces on construction sites and we have described representative hazards within these confined spaces. In the next unit, "Analyzing Confined Workspace Accidents for Their Causes," actual case histories of confined workspace accidents are examined for their immediate and their underlying causes.

Instruction Key—Unit 4

Anatomy of Confined Workspaces In Construction

Terms

1. Inherent hazards—associated with specific types of equipment within the confined space and with the interactions among them
2. Induced hazards—arising from incorrect decisions and actions

Points for Discussion

1. Examination of typical confined workspaces
 - Vaults
 - Condenser pits
 - Manholes
 - Pipe assemblies
 - Ventilation ducts
 - Tanks
 - Sumps
 - Containment cavities
 - Electrical transformers
 - Heat sinks
2. Unusual conditions
 - Confined workspace within a confined workspace
 - Hazards in one workspace entering another workspace

Questions

1. Is radiation an inherent or an induced hazard?

Explain.

2. Why are condenser pits a special problem in construction?
3. What are some of the potential hazards characteristic of pipe assemblies?
4. What specific problem relates to the confined workspaces within confined workspaces?

Answers

1. Radiation is an inherent hazard because it is generated by equipment within the confined space.
2. They are often overlooked as potentially hazardous confined spaces because they are so large.
3. The restricted dimensions make entry, exit and movement to gain a comfortable position highly difficult. Communication is not easily maintained from within the pipe. These problems are compounded if the pipe has a bend in it. Potentially hazardous atmospheres are a hazard common to almost all types of confined workspaces.
4. If only the outer space is evaluated as is often the case, workers are exposed to possible danger when they enter the inner space.

UNIT 5

ANALYZING CONFINED WORKSPACE ACCIDENTS FOR THEIR CAUSES

Accidents in confined workspaces may result from any of the following major causes:

1. Entering without testing.
2. Entering an inert space without providing adequate ventilation.
3. Using an inert gas to force a liquid out of a tank.
4. Using welding hoses and valves without periodically checking for leakages.
5. Using pure oxygen to ventilate the space.
6. Stirring up potentially hazardous sludges in a confined workspace.
7. Using air-purifying respirators in oxygen-deficient atmospheres.
8. Not checking nearby processes for possible release of toxic or flammable material.
9. Welding in a vessel without checking neighboring compartments.
10. Entering a space that has not been tested safe for entry or re-entering one, after leaving it, without retest.
11. Toxic vapors, gases, or dust in health- or life-threatening concentrations.
12. Flammable gases, vapors, or dust with potential for fire or explosion.
13. Oxygen deficiency.
14. Electric shock from portable lights, tools, or associated electrical equipment.
15. Mechanical equipment that may be defective, inadvertently or incorrectly operated, or not properly deactivated and locked out.
16. Contact with corrosives or dermatitis-producing chemicals (acids, caustics, oxidizing agents).
17. Physical hazards such as slipping and falling, or falling objects.

The following case studies will illustrate some of the situations causing death and injury to construction workers in confined workspaces.

CASE 1

A 44-year-old plumber and his apprentice on a

sewage treatment plant construction site were conducting a hydrostatic test on a thirty-inch wide steel and concrete sewer line, which empties into the bottom of an eight by four by twenty-five foot deep sump. The line was being pressure-tested to fifty pounds per square inch. Suddenly, the metal bolts holding the test plug tore loose, and a ¾-inch thick steel plate separated from the line.

The force of the blast broke the assistant's leg and ribs. He also suffered a concussion. The plumber died as a result of the blast, one arm severed and nearly every bone in his body broken.

Analysis

The cause of this accident is somewhat unusual. Close examination of the case revealed that both workers had conducted the hydrostatic test in precisely the same manner on other occasions. Apparently, either the contractor approved the test method, or he was negligent in making certain that the job was performed safely.

Although the workers were familiar with the test method, they evidently were not aware of the considerable force created by the air compressed above the water in the line. When they began to bleed off the water in the line at the test plug, they loosened the bolts holding the test plug in place. The pressure behind the loosened plug was sufficient to cause it to break away from its mounting with considerable force.

The workers should not have been in the line while pressure was applied to the water. There should have been a hose connection attached to the test plug so that a hose could be attached to facilitate bleeding the water from the system.

CASE 2

Two test technicians entered a 15-foot test pit to prepare a pump for testing at a pump manufacturing firm. The pit was not enclosed. It contained three tanks of propane, which is used for testing pumps manufactured at the plant.

The two technicians suffocated and were quickly frozen when sub-zero propane gas began to leak, displacing all the air in the pit.

Analysis

The key question here is whether propane, which is heavier than air, was used properly for this test operation. Propane by nature is both flammable and asphyxiating. Had the propane cylinders been stored outside the pit, with lines leading into the pit, the procedures would have been safer.

In addition, the contractor should have provided gas monitoring equipment in the pit to warn of oxygen deficiency and of the flammable atmosphere. Furthermore, the contractor should have instructed the workers on the hazards associated with confined workspaces, provided for a third worker to stand on the outside of the pit to observe the test procedure, and had in place rescue equipment and procedures to handle emergencies.

CASE 3

Two workers entered a missile launch tube to clean the bracket welds. The missile launch tube was twelve feet in diameter and extended downward eighty-five to ninety-five feet. The bottom of the tube's second level was thirty-five feet underground.

Approximately seven feet from the bottom of the tube, the workers began to notice that the odor of freon grew stronger. They became dizzy and nauseated. They called to be removed by the man cage and were brought to the surface. One of the workers was unconscious. All efforts to revive him failed.

Analysis

Freon, a commonly used gas for purging lines, is heavier than air. Once heated, it produces fluorine gas.

Two days before the accident, it was determined, two different workers had been in the same missile launch tube purging the freon from the valves on three lines. One worker opened the first valve in order to collect the freon in a small container. When very little freon came out of the valve, he opened the second and third and encountered the same problem. All of a sudden, freon came pouring out of all three valves. While closing the valves, the worker became dizzy and was taken out of the tube in a man cage. Unfortunately, no report was made of the incident. The tube was quietly sealed.

At the time of the accident, the workers entering the tube were not aware of the possibility of oxygen deficiency at the bottom of the tube caused by the freon gas.

Analysis indicates that the contractor did not require a test to be made of the tube before the workers entered, and that there was no ventilation or exhaust system in the tube to provide the workers with breatheable air. Furthermore, a standard operating procedure for purging or reporting unusual conditions occurring during the purge did not exist. Finally, there was no system to determine whether all the freon had been drawn from the lines.

This case indicates again the lack of worker knowledge about the hazards associated with confined workspaces and the lack of established communication and rescue procedures.

CASE 4

A pipefitter and his helper were on a ladder installing a stainless steel line thirty-one inches in diameter connecting the steam generator to a reactor coolant pump. The pipeline had just been purged with argon gas, and the purge blocks were ready to be removed. As the workers began to remove the purge blocks, the pipefitter became dizzy and fell to the bottom of the pipe, overcome due to lack of oxygen. His helper tried to rescue him, but he began to feel the effects of oxygen deficiency, too. He called for help. The pipefitter and his partner were pulled from the pipe and given CPR. But both men died.

Analysis

In this case, a confined workspace was created during the construction process. Essentially the hazardous confined workspace existed when the purge blocks were placed into the line to contain the argon gas, which is odorless, tasteless, and heavier than air.

The contractor apparently did not alert the workers to the hazards associated with argon. A more effective and safe system might have been developed to remove the purge blocks without requiring a worker to enter the line. As well, the contractor should have required that a more stable type of ladder be used, and that the workers wear life belts and life lines while in the line. A work permit for the operation, including rescue procedures and testing and monitoring procedures, should have been established.

CASE 5

A worker entered a sump hole located close to the containment area of the second unit of a nuclear power plant. The worker climbed down a wall ladder to the floor eight feet below. Shortly after he reached the bottom of the hole, he became dizzy, lost his balance, and fell to the floor. A craft foreman, observing the worker lying at the bottom of the ladder, climbed down to assist. When he reached the bottom of the ladder, he was overcome, and fainted over the body of the first worker. A carpenter, seeing what had happened, descended the sump hole to help the two workers in distress. As soon as he reached the two workers, he, too, was overcome and fell on top of them. A medic at the jobsite was called and descended into the sump holding his breath. He tied a line around the carpenter, climbed out of the hole, and assisted in pulling the carpenter out. This procedure was repeated for the second and third workers.

Analysis

Oxygen deficiency caused by argon gas was suspected as the probable cause. The argon gas was probably present from heliarc operations conducted earlier.

The *underlying* causes are numerous. The first worker entered the sump without first determining whether the atmosphere was safe. He didn't wear respiratory equipment. And he entered the sump without securing the aid of another worker to stand by.

Negligence on the part of the worker? Again, probably not. The two who tried to save him before the medic was called also entered the sump without respiratory equipment. It seems that the medic was the only one who was aware that a hazardous atmosphere might be the problem. Therefore, this accident, like the others, apparently stems from the contractor's negligence.

CASE 6

A pipefitter foreman had part of his crew working on a 561-foot elevation of a containment vessel and part of his crew working at an elevation somewhat below the 541-foot elevation. One of his pipefitters dropped a grinder from the 561-foot elevation and watched it fall into a 24-inch (I.D.) pipe on the 541-foot elevation. Two pipefitters working next to the pipe observed the incident. A short time later, one of these pipefitters climbed into the 24-inch pipe and recovered the grinder. In the meantime, the pipefitter foreman was unaware that the grinder was recovered and, later in the shift, decided to go into the pipe to retrieve it.

This foreman was generally knowledgeable of the hazards of entering confined spaces, and he knew safe entry procedures. Unfortunately, he disregarded them this time.

Upon entering the pipe, he was unable to find the tool and spent extra time searching for it. Due to a lack of oxygen in the pipe, he lost consciousness. He was later found by members of his crew and removed. He was pronounced dead.

Analysis

After the incident, the air in the pipe was tested. Approximately one foot below the inside edge of the pipe, the alarm on the test instrument sounded, indicating both oxygen deficiency (9%) and a hazardous level of combustible gas at 40% caused by acetylene in the pipe.

CONCLUSION

This unit shows how a combination of factors will cause accidents in the confined space. The next unit, "Evaluation of Confined Workspaces," tells how the hazards of any given confined workspace may be assessed so that such accidents may be prevented.

Instruction Key—Unit 5

Analyzing Confined Workspace Accidents for Their Causes

Points for Discussion

Case 1

Hydrostatic test at sewage treatment plant construction site

Test plug tears loose

One injured, one dead

Analysis

Incorrect test method

Case 2

Propane gas leak in a test pit at pump manufacturing firm

Both workers dead

Analysis

Improper use of propane

Lack of gas monitoring equipment

Inadequate instruction for workers

Lack of third worker and rescue equipment

Case 3

Cleaning operation in missile launch tube

Freon contamination

Both workers ill, one fatally

Analysis

Previous operation to pump freon resulted in a leak

No report made

No test made before entry

Case 4

Stainless steel line installation on reactor coolant pump

Oxygen deficiency

Both men dead

Analysis

Argon gas was used to purge the pipeline

Insufficient instruction for workers

Unsafe system for removal of purge blocks

Lack of proper safety equipment

Case 5

Sump hole at nuclear power plant

First worker collapses

Two more enter to help, both also collapse

Medic enters holding his breath

Analysis

Oxygen deficiency caused by argon gas suspected

No test made before first worker's entry

No second worker to assist from outside

No respiratory equipment

Insufficient instruction of workers

Case 6

Pipefitting crew on containment vessel

Grinder is dropped into a pipe, later retrieved

Foreman enters pipe to recover the grinder

Foreman dies of oxygen deficiency

Analysis

Foreman knew proper entry procedures, but disregarded them

Oxygen deficiency

Hazardous level of acetylene gas

Questions

1. What major characteristic do five of these six accidents have in common?
2. What are some other similarities among these case histories?
3. What was the basic cause of the first case history studied?

Answers

1. Failure on the part of the contractor to provide adequate instruction contributed greatly to the accident.
2. Lack of test before entry was common, as was a lack of a worker to assist from outside the space and inadequate or non-existent rescue equipment and procedures.
3. The contractor was approving, and the workers were using an unsafe test method.

UNIT 6

EVALUATION OF CONFINED WORKSPACES

Confined workspaces can become unsafe as a result of: possible atmospheric contamination by toxic or flammable vapors, or oxygen deficiency or excess; possible physical hazards located in or introduced into the confined workspace; the possibility of liquids, gases, or solids being admitted during occupancy; and the occupants being isolated from help in case of need.

Therefore, all confined workspaces where such hazards may develop should be evaluated. This evaluation should determine the nature and extent of the hazards located before workers are required to enter the space. During the planning process for work in operating plants or facilities, client safety personnel should be consulted before workers enter confined spaces.

The hazard evaluation becomes the decision-making tool in deciding how much monitoring is needed as well as what types of personal protective and safety equipment workers will need.

EVALUATION OF THE CONFINED WORKSPACE BEFORE ENTRY

No matter what type of confined workspace is to be entered, its potential hazards must first be assessed.¹ Atmospheric contaminants, for example, are often encountered in the confined workspace. An examination of process operations will reveal the generation of any gases, vapors, fumes, and smokes which have toxic effects on workers. Other conditions, although not necessarily toxic (such as oxygen deficiency, or irritating or combustible substances), should be assessed to determine their ability to interfere with a worker's decisions and actions.

Evaluation of Confined Workspaces—Hazardous Atmospheres

Let's examine the major categories of confined space hazards that must be evaluated before workers may enter.

First, the present and/or previous contents of the space which may result in the presence of flamma-

ble or explosive, toxic or irritating, or oxygen-deficient atmospheres must be considered.

Toxic levels of substances in the confined workspace may result from a number of factors. For example, substances such as methane gas that are either inherent in the confined space or introduced into it may ignite and explode. Some substances that are relatively harmless by themselves may form hazardous mixtures in combination with other substances. Other substances, including solvents and inert gases, are toxic in and of themselves. Toxic fumes, such as welding fumes, inert gases, or the vapors from solvents, may remain in the confined space from previous operations performed within the space.

Oxygen deficiency may result from a number of causes as well. These include fermentation, rust, the use of inert gases such as nitrogen to clear combustible gases, and welding operations within the confined space.

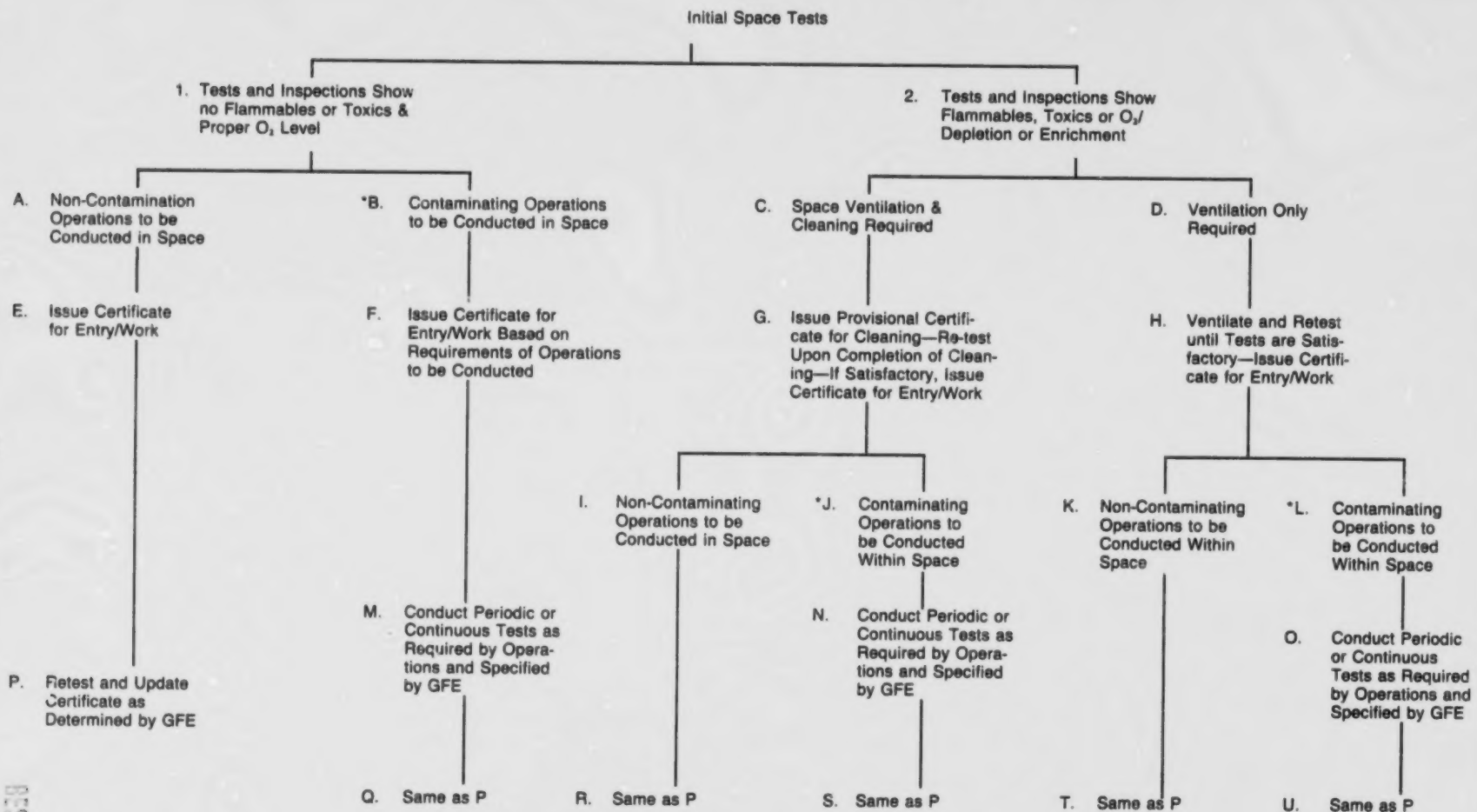
Figure 6.1 illustrates the general conditions which may be encountered on initial evaluation of confined workspaces, and those which may be caused by the conduct of operations within the space which may introduce hazards into the space. It is emphasized that Figure 6.1 addresses *only general conditions* to illustrate basic confined workspace testing and certification procedures, and does not attempt to cover special requirements and considerations relating to items such as hot work, lockout, tagout, blanking-off, isolation, cleaning procedures, etc. These areas are addressed separately elsewhere within this manual.

Location and Configuration

The evaluation should also examine the space, and any problems thereof, including restricted access, obstructions, and remoteness, which may inhibit or interfere with movement, ventilation, rescue, or firefighting, to name a few.

Both factors may compound any hazards already in the confined space in a number of ways. An

CONFINED WORKSPACE ATMOSPHERIC TESTING FLOW DIAGRAM



*Contaminating operations are those which introduce, or have the potential to introduce, hazards into the space including hot work, spray finishing, coatings, solvents, inert gases, or other flammables, toxics, O₂ displacement, depletion, or enrichment.

(NOTE: GFE = Gas Free Engineer)

Figure 6.1. From NAVSEA S6470—AA-SAF-010.

explosion or fire hazard, for example, will be increased considerably if a worker performs a spark-producing task within the confines of a very small confined space or at the point of entry. An example would be a worker required to perform welding work near the flange of a 36-inch pipe assembly in the presence of flammable and/or explosive solvent vapors.

The size of the confined workspace can contribute to the overall hazard in another way, as well. If the space is very small, workers may be unable to maneuver away from hazards such as contact with caustic substances or the arc or light of welding operations. Or, they may suffer strains or abrasions while attempting to move around in the confined space. Cramped conditions may cause one worker to strike another with a tool or with a piece of material.

Operations in the Space

The types of operations which are conducted within the space must also be determined, particularly those which by their very nature involve toxic substances, flammables, oxygen depletion or over-enrichment, or ignition sources.

Workspace Equipment

Fixtures, devices, or equipment within the space may create or contribute to hazardous conditions. Such equipment includes piping systems, conduits, ducts, machinery, pressurized lines, and so forth.

Boundary Spaces

The boundary spaces and their contents must be investigated to ensure that no hazards will be created in these spaces by the operation to be conducted.

Explosions or Fire Hazards

Explosion or fire may be caused by a spark-generating activity that may occur in the confined workspace, including welding, or the use of unapproved electrical tools, portable lights or communication and test equipment.

Electrical Hazards

Electrocution or electrical shock in the confined workspace may be caused by any electrically "hot" sources in the confined workspace. Power tools must be double-insulated or connected to a ground-fault circuit interruptor, and all flexible cords and connections must be of the approved variety.

Crushing

Workers may be caught or crushed in the con-

fining workspace. An example of such hazards would be a worker required to enter a confined workspace in close proximity to a piece of electrical or mechanical equipment which is not locked out.

Unstable Conditions

Unstable conditions within the confined workspace are another hazard. Such unstable conditions include working in wet spaces and working in confined workspaces with unstable walls and inadequate shoring (or none at all).

Falling Objects

Objects falling into the confined workspace may strike workers working inside. (Note: This condition includes situations both where workers are able and where they are unable to maneuver to safety. Obviously, the latter situation is the more hazardous.)

Falls

Falls in the confined workspace may be caused by a number of factors, including:

1. Wet or oily conditions of the work surface;
2. A sloped configuration;
3. Falls through the confined workspace (for example, through an unsupported section of a ventilation duct);
4. Tripping over objects;
5. Holes in floors of the space;
6. Uncertain footing due to poor lighting;
7. Uncertain footing due to uneven surfaces;
8. Unstable placement of ladders used for entry and exit.

Entry and Exit Injuries

Workers may be injured while entering or exiting the confined workspace. For example, does the entrance have sharp edges, is it located at a high level, or does it provide for a cramped entry?

Temperature Extremes

The confined space may cause workers to come in contact with temperature extremes. The temperature in the space may be so high as to cause heat exhaustion or so low as to cause frostbite.

CONCLUSION

This unit examines factors that must be evaluated to determine the safety of the confined space. In the next unit, "Preliminary Steps for Entry into Confined Workspaces," we will describe steps that must be taken after the hazards have been evaluated and before workers may be allowed to enter.

Notes

1. This section is adapted from Steve P. Krivan, "Confined Space Entry: Can the Deaths and Injuries be Eliminated?" *Professional Safety*, September 1982, p. 15.

Reference

1. Naval Ships' Technical Manual, NAVSEA S9086-CH-STM-030/CH-074, Volume 3, "Gas Free Engineering."

Instruction Key—Unit 6

Evaluation of Confined Workspaces

Points for Discussion

Factors to evaluate before entry

Hazardous atmospheres
Location and configuration
Operations within the confined space
Workspace equipment
Boundary spaces
Explosion or fire hazards
Electrical hazards
Crushing
Unstable conditions
Falling objects
Falls
Entry and exit injuries
Temperature extremes

Questions

1. How many basic types of hazardous atmospheres are found in confined spaces and what are they?
2. Describe the condition that is usually the cause of an explosion or fire hazard and name four

activities that contribute directly to the hazard.

3. What are some ways to reduce electrical hazards?
4. Name two common unstable conditions in confined spaces.

Answers

1. The three types of hazardous atmospheres in confined spaces are toxic or irritating, flammable or explosive, and oxygen-deficient.
2. The hazard is usually the result of a combination of combustible gases and spark or heat from activities such as welding or using electrical tools, light bulbs, or matches.
3. Power tools should be double-insulated or connected to a ground-fault circuit interruptor; all flexible cords and connections should be approved.
4. Excess moisture and inadequate shoring of unstable walls.

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UNIT 7

PRELIMINARY STEPS FOR ENTRY INTO CONFINED WORKSPACES

INTRODUCTION

As discussed earlier, confined workspaces may contain hazardous atmospheres. Therefore, a trained person should test the atmosphere of the space before the initial entry and before any subsequent entries, to determine the nature and extent of any such hazard. Continuous monitoring while the worker is inside may also be necessary.

Actions performed and decisions made before workers enter a confined workspace may make the difference between a safe operation and a disaster.

CLEANING

Preliminary Precautions

A precleaning orientation and training session should be conducted for each atypical task to inform workers of unusual cleaning procedures, potential hazards, sources of ignition, and control methods.

A trained person should be assigned to check the materials contained in the confined workspace since the last thorough cleaning, the amount of residual material and sediment, and the overall physical condition of the entire structure. Also, a check should be made to determine whether vapors may be accumulating from other tanks or piping.

Workers should be trained in the proper use of personal protective and mechanical equipment to be used in the work process.

Where cleaning operations involve the use of chemical solvents, a test should be made to determine the flammable and/or toxic properties of the cleaning solvents as an integral part of the initial preparations.

Any or all of the following preventive measures should be used (see ANSI Z117.1):

1. Posting or barricading the area to prevent unauthorized entry of persons and vehicles;
2. Prohibiting hot work or other work in the area that might create a source of ignition;
3. Ensuring that electrical equipment and portable lighting that will be used are of a design that will not provide a source of ignition (see

also National Electrical Code Articles 500, 501, and 502; ANSI/NFPA No. 70[C1]);

4. Prohibiting smoking and the carrying of matches or other sources of ignition into the potentially hazardous area. A safe smoking area should be established nearby to minimize unauthorized smoking.

Fire Protection

Also during the preliminary preparation for entry into a confined workspace, a number of fire control measures should be instituted.

All access ladders, floors, components, etc., requiring protective wrappings should be covered with flame-retardant material.

Flammable liquids (i.e., acetylene, paints, solvents, etc.) must be stored in Underwriters Laboratory (UL) or Factory Mutual (FM) approved flammable liquid container/dispensers. The amount of such flammable liquids should never exceed the amount necessary to perform the work each shift.

Fire extinguishers suited to each class of fire that could possibly occur within the confined space should be readily accessible in the event of fire emergencies.

Cylinders containing oxygen, acetylene, or other fuel gases should never be taken into confined workspaces.

Approved metal containers should be provided to store all rags, brushes, and other combustible materials used within the confined space. These containers should be emptied at each shift.

A pre-fire plan which includes evacuation, rescue, equipment, etc., must be in effect before work begins in a confined workspace. Specific attention should be given to extrication of workers from the confined workspace in emergencies.

Flammable gas equipment, hoses, and so forth, should be inspected by the user before use within the confined space to assure that they are free of defects.

Combustibles in the confined workspace which

are exposed to flames or sparks should be either removed or adequately covered to prevent ignition.

In order to eliminate a possible fire as a result of gas escaping through leaking or improperly closed welding torch valves, the torch and hose should be removed from the confined workspace whenever the welding is completed or the workspace is exited. Open-end fuel gas and oxygen hoses should be immediately removed from confined workspaces when they are disconnected from the torch or other gas device. It is good practice to close all gas manifold isolation valves at the end of the shift.

ISOLATION OF TANKS/VESSELS IN PREPARATION FOR EMPLOYEE ENTRY

The confined space should be completely isolated from all other systems and equipment. Positive measures must be taken to prevent hazardous substances—either solids, liquids, or vapors—from entering the confined space while workers are inside. In cases where lines have contained hazardous fluids or inert gas, or where they contain fluids at high pressures or temperatures, the lines should be disconnected by one of several methods.

One method involves removing a fitting or section in the conductor line as close as possible to the confined workspace, and blanking or capping the pressure end that leads to the confined space. If possible, the conductor line should also be misaligned. The blank or cap should be identified to indicate its purpose. Any holes should be blanked and drains or overflow lines disconnected or blanked if they extend into a sewer from which steam or fumes could be conducted back into the confined space, or if they connect to other equipment or extend to a remote location. Conductor lines to be disconnected or blanked include, but are not limited to, steam connections, water, refrigerants, or air lines of the jacket. Blanking or capping prevents flow from disconnected ends entering a confined space opening or draining on to workers on the outside.

Blanks or caps should be made of the same material used in the blanked or capped conductor line. The blanks or caps should have the same wall thickness and tensile strength as the blanked conductor line.

A second method of disconnecting involves inserting a suitable full-pressure blank in piping between flanges nearest to the confined workspace.

Finally, disconnecting may be accomplished by closing, removing handles, and locking and/or tag-

ging all valves in the piping leading to the confined workspace. Any drain valves must be checked to ensure that they are not plugged.

LOCK-OUT AND TAG-OUT OF EQUIPMENT IN PREPARATION FOR EMPLOYEE ENTRY

A confined workspace may itself move or may contain agitators, fans, or other moving parts that are a potential hazard to workers. Lockout procedures must be followed to minimize potentially harmful movement.

A lock and/or a tag may be placed on the open circuit breaker or line switch controlling moving hazards to indicate that workers are working on equipment.

A belt or other mechanical linkage may be disconnected and tagged to indicate that workers are working on the equipment if the power source cannot be easily controlled.

Locks, tags, blanks, or other protective factors should not be removed, nor the system energized, while workers are inside the confined workspace.

Line-disconnect switches supplying power to any mechanical mixers, agitators, pumps, cover or door actuators and radiation gauges should be tagged and locked in the "OFF" position. *It is not adequate to lock a push-button station*, as it may still be possible to energize the circuit.

CLEANING AND PURGING THE SPACE¹

Once the space has been isolated, it should be cleaned, purged, tested, and ventilated. The extent of these procedures depends on the nature of the material in the space. Decomposition or other chemical reactions that may have affected the atmosphere, the level of residue and amount of scale buildup on the inside walls, the configuration of the space, and the size and location of manholes, hatches, and vents must be considered.

A confined space that has been used to store liquids, chemicals, or food should be purged of all residue. Even small amounts of remaining materials can create lethal quantities of hazardous gases or vapors in a confined space. Three basic steps should be followed to perform a cleaning operation.

First, the confined space should be emptied and any residue drained or pumped out.

Second, the confined space should be flushed, if possible. Flushing can range from simply hosing the walls and floor to completely filling and draining the container.

Finally, it may be necessary to purge the confined space further with steam, nitrogen, or an inert gas

after it has been flushed. The environment inside the space should be tested at this point to determine whether further purging is necessary (testing procedures will be discussed in later units). If sediment adheres to the walls or floor, or if corrosion scale or rust is heavy, purging is almost always necessary.

If steam is used, the confined space should be purged long enough to flush residue from the rust and scale. However, if the confined space has contained materials that could possibly build static electricity, steam should not be used, since the condensate might generate a spark that could ignite any combustibles within the vicinity.

Purging Operations Using Inert Gases

Whenever a piece of equipment is pressed up with nitrogen, argon, or carbon dioxide purge blanket and could be entered by personnel, all accesses should be barricaded and posted.

Supervisors of workers introducing the purge are responsible for assuring that the equipment is sealed to prevent leakage to any unknown areas.

When the purge blanket is taken off, and before workers enter the confined workspace, the space should be vented to an outside area where there are no other confined workspaces nor any possibility of accumulation. The workspace should then be tested.

Testing the Atmosphere²

It is important that anyone required to work in a confined space know the three major types of hazardous atmospheres that can be present in any confined space: oxygen-deficient, combustible or explosive, and toxic or irritant.

Special hazards that might arise because of the physical properties of the suspected contaminants or the size or shape of the space should be considered. It should also be determined whether the contaminant is lighter or heavier than air, whether it has a place to pocket, and whether it can create static electricity.

It must be remembered that instruments used to test for any type of hazardous atmosphere should be inspected periodically and any necessary maintenance or repair work performed immediately. Supervisors should insure that an entry permit or caution tag is posted by the confined space entrance and that the permit or tag is always signed after an oxygen check has been made. Further, the supervisors should forbid entry into the confined space unless the permit or tag has been signed. In

situations where permanent meters have been installed in a particular confined workspace, the permit or tag need be signed only once per shift before worker entry.

In areas where oxygen deficiencies are suspected, the atmosphere should be tested. An oxygen concentration below 19.5% is oxygen-deficient. If the concentration within the space is below this percentage, no one should be allowed to enter the space until proper measures have been taken. The oxygen check must be made within one hour of entry, unless the aforementioned permanent monitors are installed, in which case the atmosphere may be checked once per shift.

Such monitors should be installed whenever possible. They provide visual/auditory alarms whenever the oxygen level within the space is dangerously low. The monitors must be inspected each day by a trained person who will verify their operational effectiveness.

Any workspace found to be oxygen deficient must be:

1. Ventilated with fresh air for thirty minutes;
2. Posted with tags or warning signs prohibiting entry;
3. Re-checked before workers are permitted to enter.

It must be kept in mind, too, that a confined space that tests free of any type of hazardous atmosphere may not remain safe. Monitoring should continue while anyone is working inside. And should a worker leave the confined space, a test of the atmosphere must be repeated before re-entry.

VENTILATING THE CONFINED SPACE

The confined space should be thoroughly ventilated, preferably by some method of mechanical exhaust to avoid recirculation of contaminated air. All electrical ventilating or air-moving equipment must be grounded. After the tank or vessel is cleaned and ventilated, the mechanical exhaust system should be kept operating. If decontamination involves flammable liquids, vapors, gases, or dusts, all sources of ignition should be eliminated. To eliminate static electricity and prevent auto-ignition of flammables, steam lines should be electrically bonded to the tank or vessel if it contains, or may contain, any flammable material.

The space should be sufficiently ventilated that levels of combustibles do not exceed ten percent of their lower explosive limit (LEL), nor toxic substance levels their respective threshold limit values. Continuous monitoring and ventilation of

the confined space after the initial ventilation may be necessary in cases where the contaminant may become re-introduced while work proceeds. Ventilation will be discussed in more detail in Unit 12.

In areas where adequate ventilation and/or exhaust cannot be provided, workers must wear appropriate respiratory protection.

SPECIAL HAZARDS

Whenever work that generates heat is performed in a confined space, or when the inner or outer walls of the space are to be heated, all residue, scale, and rust inside the space must be removed. While the work is being performed, the atmosphere should be checked frequently for the accumulation of combustible vapors or toxic substances, and for oxygen deficiency or excess. Hot work will be discussed in further detail in Unit 13.

Ideally, semicontinuous monitoring instruments should be set up in the space. As well, all piping within the space must be flushed with water or blown with steam or air and monitored to ensure that combustibles remain below 10% LEL. If welding is to be performed in spaces that have contained combustibles, all residue, including dry scale or sediment, must be removed. If it is impossible to remove the dry combustible materials within the space, they should be covered with a noncombustible blanket.

When materials are present that can ignite spontaneously on exposure to air, they should be kept wet until they can be scraped or sanded from the walls and floors, and these scrapings disposed of. Fire extinguishing equipment should be available in the confined space. (Any time a fire occurs in a confined space, incidentally, the atmosphere within the space is likely to become oxygen-deficient.) If work that generates heat is performed on the walls of a vessel adjacent to another structure containing combustibles, the adjacent vessel should also be cleaned, purged, and ventilated.

Applying flame to a surface covered with a preservative or a protective coating can release toxic gases or vapors. Sufficient ventilation must be provided in the space to remove any such vapors or gases.

Any time combustible vapors may be released, purge and ventilation lines and equipment should be grounded to discharge any buildup of static electricity. Care must also be taken not to introduce toxic materials or combustibles from spraying, painting, or cleaning into any space that has been purged and tested. If contamination from such

materials is suspected, the atmosphere should be retested.

EQUIPMENT USED IN CONFINED WORKSPACES

Hand Tools and Equipment

Hand tools should be clean and in good condition, and should be selected carefully according to the uses intended. Non-sparking tools should always be used in flammable and explosive environments.

Electrical Tools and Equipment

Whenever possible, air-operated pneumatic power tools should be used in confined spaces. Where the use of portable electrical tools cannot be avoided, an effective grounding system should be instituted, or ground fault circuit interrupters used, to protect employees from electrical shock.

Temporary lights should be equipped with guards to prevent accidental contact with the bulb and should be operated at a maximum of 12 volts.

Employees performing electrical welding in confined spaces must use such personal protective equipment as conditions may require. Welding and cutting torches should never be taken into the tank or vessel until they are ready to be used and should be removed from the tank or vessel immediately after use. Cylinders of oxygen or other gas should never be taken into the confined space, and should be turned off at the cylinder valve when not in use. Fire extinguishers should be at the location of welding or cutting and at the observer's station.

Signs and Barricades

Signs should be posted near the confined space to keep out unauthorized persons, to prevent starting potentially harmful operations in the vicinity, and to help guide emergency personnel should it be necessary.

Open pits and hazardous tank operations require barricading with substantial railing 42" high with midrail and toe boards or equivalent protection to prevent kicking objects lying on the floor or ground into the pit. Rope with streamers at the 42" level is recommended for closing aisles in adjacent areas. Flashing lights on barricades are necessary when pits are open at night or in dimly lit areas inside.

Protective and Safety Equipment

Necessary rescue equipment, including life lines, harnesses, belts, stretchers, mobile cranes or hoists, and so forth, must be readily available in emergencies. Ladders used in confined spaces should be lashed at the top and, if possible, at the bottom.

Emergency lighting should be provided at all entrances and exists. When this is not practical, workers who are required to enter a confined workspace which may be subject to a blackout should be provided with flashlights.

Suitable protective equipment varies with the work to be performed and the type of atmosphere present. The equipment may include a respiratory protection device; protective coveralls (typically, acid-resistant or rubber); and eye, hand, and face protection. Proper selection and maintenance of respiratory protective equipment is especially important; it can mean the difference between life and death.

STANDBY OBSERVER

While workers are inside the confined space, requiring the use of harnesses, lifelines and breathing apparatus, a trained, qualified standby observer must observe the operation from outside the confined space. This is known as the "buddy system." The "buddy" should have available entry safety equipment and should be aware of the conditions of personnel within the confined space at all times. He may pass tools, but he must not have any other job which will take his attention away from the workers in the confined workspace and/or which will interfere with attempts to render any emergency assistance that becomes necessary.

Communication

It is of critical importance that workers not enter a confined workspace until adequate communication has been established between those in the confined workspace and those on the outside.

A system must be established whereby the standby observer will always keep the workers in the confined space in his vision. When this is not possible, a clearly understood signal system should be established and rehearsed prior to the start of the operation either by radio or line-jerk signals.

Communication may also be accomplished by

utilizing one (or a combination) of the following methods:

1. Visually, by the "buddy" outside the space.
2. Vocally, by the "buddy" outside the space.
3. By telephone—hard wire.
4. By electronic radio transmitter—FM radios.

ISSUANCE OF ENTRY PERMIT

The supervisors of all workers involved should review and complete the authorization form jointly with the facility safety department or designated representative. The supervisor must ascertain by personal investigation, immediately before tank entry and before signing the authorization, that the entry and subsequent work will be safe.

No authorization is valid except for the job, location, persons, and time specified. *Commencement of a new shift will always require re-evaluation and re-endorsement of an authorization by new shift supervision.* To ensure continuation of safe conditions should a pause of appreciable duration occur during the carrying out of a job, such as lunch periods, breaks, etc., the space should be re-evaluated before the job is allowed to resume.

No worker should enter any confined space without reporting to and securing approval from his immediate supervisor. The supervisor should discuss the project in detail with those entering the confined space. He should also review the hazards of the product or other materials to which they may be exposed.

The following unit, "Safe Entry Permits," provides specific information on the completion and authorization of entry permits.

Notes

1. Adapted from "Working Safely in Confined Spaces . . . Evaluating the Hazards," by George L. Morse and Richard L. Swift, in *Plant Engineering*, January 21, 1982.
2. Adapted from "Working Safely in Confined Spaces . . . Establishing and Following Correct Procedures," by George L. Morse and Richard L. Swift in *Plant Engineering*, April 29, 1982.

Instruction Key—Unit 7

Preliminary Steps for Entry Into Confined Workspaces

Terms

1. Hazardous atmospheres
 - a. Oxygen-deficient
 - b. Toxic or irritant
 - c. Flammable or explosive
2. Lockout/Tagout

A process ensuring that the circuit of the equipment is de-energized and that it does not become re-activated while work proceeds.
3. "Buddy system"

A practice whereby one attendant stands outside the confined workspace to provide assistance and possible emergency aid to the worker(s) within the space.
4. Entry permit

A form, detailing hazards found and appropriate controls taken, that must be signed and posted outside the confined space before entry can be made and work begun.

Points for Discussion

1. Preliminary precautions
 - a. Precleaning orientation and training
 - b. Contents check
 - c. Barricading the general area to prevent unauthorized entries
 - d. Prohibiting hot work or other sources of ignition in the area
 - e. Providing safe types of electrical equipment
2. Fire protection
 - a. Proper storage for flammable liquids
 - b. Suitable fire extinguishers readily accessible
 - c. Prohibition of cylinders containing fuel gases
 - d. Provision of metal containers for storage of combustible materials
 - e. Pre-fire plans drawn up
 - f. Inspection of all pertinent equipment
 - g. Protective coverings placed on non-removable combustibles

3. Isolation
 - a. Locking out of moving equipment
 - b. Placing tags on locked-out equipment
4. Cleaning and purging
 - a. Removal of contents
 - b. Flushing of space
 - c. Purging with steam, nitrogen or other inert gas
5. Testing the atmosphere
 - a. Test for all three types of hazardous atmosphere
 - b. Fixed monitors for continuous testing
6. Ventilating
7. Special hazards
8. Equipment used in confined workspaces
 - a. Hand tools and equipment
 - b. Electrical tools and equipment
 - c. Signs and barricades
9. Protective and safety equipment
 - a. Rescue equipment
 - b. Emergency lighting
10. "Buddy system"
11. Entry permit

Questions

1. Along with determining what type of hazardous atmosphere, if any, is present within the confined space, what related factors should be assessed?
2. Why is the locking of a push-button station an inadequate method of lockout?
3. Why should hot work be avoided in the confined workspace whenever possible?

Answers

1. It should be determined whether the contaminant is lighter or heavier than air, whether it has a place to pocket, and whether it can create static electricity.
2. It may still be possible to energize the circuit by some other means.
3. Hot work may create a source of ignition, increasing the fire hazard within the confined workspace.

UNIT 8

SAFE ENTRY PERMITS

The purpose of a work permit program is threefold in that it provides:

1. A written record by which the person in charge of an area authorizes a workman or a work crew to do a specific job in the area under the supervision of the issuer of the permit.
2. A written record of steps to be taken in the preparation for the work to be done as specified in the permit.
3. A written record of the safety precautions which must be followed to ensure the safe completion of the work.

An entry permit is so vital, in fact, that no confined space should ever be entered without one. Whenever any type of work is to be conducted within a confined workspace, the workers must know the hazards associated with the specific work to be performed as well as how those hazards will be affected by conditions in the confined space and proper safety measures to control the hazards. An entry permit provides this information. The information given on the permit is acquired through a hazard assessment of critical operations as well as an assessment of the atmosphere within the space.

DESIGNATION OF A QUALIFIED PERSON TO AUTHORITY

The contractor should appoint and train persons for the responsibility for overseeing the evaluation of and entry into confined workspaces, who will be responsible for evaluating and monitoring the work environment to determine the hazards associated with a confined space.

They will sign the entry permit, along with the supervisor who has direct responsibility for the work to be performed. The designated entry authority and the supervisor will survey the upcoming operation, re-evaluate the hazards, and assure that all workers entering the confined space understand the hazards and their own responsibilities. The person performing the monitoring of the atmosphere, if other than the entry authority, must sign the permit in the allocated place.

ENTRY PERMIT DESIGN

Entry Permits

Entry permits are required whenever anyone must enter a confined workspace to perform work of any type.

Factors that must be considered in the design of entry permits include the area involved, the type of work to be performed in the area, and the materials to be used.

If there are combustible materials or an explosive atmosphere, a permit for hot work should be designed when the work to be performed and equipment to be used produce a source of ignition. Such processes include:

- Welding and cutting
- Torches, open flames, and electric heaters
- Hot riveting
- Hot forging
- Salamanders
- Internal combustion engines
- Portable electrical tools
- Grinding
- Drilling
- Chipping
- Soldering
- Sandblasting
- Thawing
- Sparks from hand tools.

If there is no danger from fire or explosion, but the hazards involve a toxic atmosphere, the permit must be designed to provide a safe work procedure where toxic fumes and vapors, toxic dusts, chemical mists, and corrosive chemicals will be involved. In these atmospheres, the use of approved personal protective equipment may be necessary if the hazard cannot be eliminated. It should also be determined whether the atmosphere is either oxygen-deficient or oxygen-enriched.

Permit design may vary from very simple to very complex. On jobs with a minor exposure to fire, the permit may be very simple. Jobs with moderate exposure to fire involving combustible material would

require a more comprehensive work permit. And jobs with high exposure to fire involving combustible material, flammable gases and liquids will require very complex permits and procedures. The complexity of operations in construction makes it impossible to outline the variety of the work permit programs which would adequately cover all conditions. The work permit should be designed according to specific need.

Every entry permit must identify the specific confined workspace to which it applies, and the date and time of issuance.

The permit must have an expiration date and time after which the safe condition expires and a "safe" notation is not valid. Normally, a permit should not certify a safe condition for longer than four hours. Safe time limits for permits should never exceed one shift. Because conditions in the confined workspace could change during the period certified safe, the confined workspace must be tested periodically, perhaps even continuously, depending on conditions, to insure a safe condition for the work to be performed.

The permit should indicate conditions under which a safe operation may be maintained. Examples include continuous or frequent testing, or maintenance of forced ventilation arranged in such manner as will adequately ventilate the space in which work is to be performed.

The permit should also indicate whether work may be performed on piping or other hollow structures or fixtures. Examples include, but are not limited to, piping systems such as intake, discharge, and distribution pipes.

CHANGING CONDITIONS WILL VOID PERMITS

If conditions within the workspace change, work must stop so that the workspace can be re-evaluated.

Checklists

The permit should specify that the following areas, where applicable, have been reviewed and confirmed:

1. Location and description of the work to be done.
2. Chemicals and other hazardous substances in the confined space before entry.
3. Procedures used to decontaminate the space.
4. Oxygen content checks and their frequency, if they are not to be continuous.
5. Explosive gas checks and their frequency if monitoring is not to be continuous.

6. Short-term exposure limit and threshold limit value of potential contaminants from the initial hazard assessment.
7. Radiation level checks and frequency of monitoring, if applicable.
8. Complete isolation checklist—
 - a. Blanking and/or disconnecting;
 - b. Electrical lockout;
 - c. Mechanical lockout.
9. Special clothing and equipment
 - a. Personal protective equipment and clothing;
 - b. Safety harness and lifelines;
 - c. Approved electrical equipment;
 - d. Tools approved for use in accordance with the National Electrical Code's Hazardous Location Classification (Article 500) as follows:

Class 1 Locations—those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

Class 2 Locations—those that are hazardous because of the presence of combustible dust.

Class 3 Locations—those that are hazardous because of the presence of easily ignitable fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitable mixtures.

10. Atmospheric test readings—
 - a. Oxygen level;
 - b. Flammability and/or exposure levels;
 - c. Toxic substance levels.
11. Atmospheric monitoring while work is being performed.
12. Personnel training and complete understanding of the hazards.
13. Standby person(s) as named on the permit.
14. Emergency procedures and location of first-aid equipment.
15. Special check points.
 - a. Gas test;
 - b. Lockout of electrical equipment;
 - c. Warning tags attached to locked out equipment;
 - d. Cleaning, purging, and blocking off or disconnection of all equipment and attached piping;
 - e. Provision of ventilation;
 - f. Grounding of equipment;

- g. Possible hazards presented by adjacent equipment or materials;
 - h. Possible ignition of floors, walls, ceilings, or adjacent materials by flying sparks;
 - i. Unnecessary use of heat to perform the work;
 - j. Advisability of moving any of the equipment outside;
 - k. All plant operators informed of the work to be performed.
16. What individuals or departments will be affected and how.
 17. Procedures and job methods to be followed by crew members.
 18. Tools and equipment required.
 19. Equipment thoroughly steamed or ventilated.
 20. Equipment thoroughly depressurized.
 21. Equipment thoroughly flushed with water.
 22. All connections blanked off.
 23. Effect of wind direction on work process.
 24. Removal of all rubbish and combustible material.
 25. Any sewers or basins in need of protection.
 26. Provision of proper fire extinguishers.
 27. Examination of equipment to be worked on to make certain that it is free from oil or chemicals.
 28. Is oxy-acetylene burning permitted?
 29. Is electric welding permitted?
 30. Is welding and curring necessary?
 31. Are barricades required around the work area?
 32. Is the temperature bearable?
 33. Is an escape ladder provided?
 34. Are approved lights provided?
 35. Is there any other work in the area which might create hazards to a worker in the confined space?

DISTRIBUTION OF ENTRY PERMITS

When testing, inspection, evaluation, space cleaning, and/or ventilation have been completed as needed, an entry permit can then be issued.

This certificate indicates the conditions found to exist at the time the permit is issued, any requirements necessary to maintain the conditions

within the space, and any requirements associated with the operations which are to be conducted within the space.

One copy of the entry permit is to be posted at the main entrance or the most commonly used access to the workspace. All other accesses into the workspace should be posted to prohibit entry by unauthorized personnel. See Appendices A through D for samples of entry permits.

Recordkeeping

It is important that a recordkeeping scheme be developed to ensure that all entry permits issued for spaces evaluated, tested, monitored, and inspected are maintained and kept for the duration of the project. Should a worker be injured or become ill as a result of working in a confined workspace, the contractor should maintain the records on the particular workspace indefinitely, or until it is determined that workers' compensation and/or tort litigation has been concluded.

The first portion of this manual has dealt primarily with background information and practices to be instituted before work begins in the confined workspace. Beginning with the next unit, "Hazardous Atmospheres in Confined Spaces," individual hazards and procedures will be examined separately in fuller detail.

References

1. Canada Technical Service Memorandum #17. Revised August 1969.
2. "Confined Space Entry Procedures for Operating Facility Projects," a company pamphlet distributed by Brown and Root.
3. *Gas Free Engineering*, NAVSEA S9086-CH-STM-030/CH-074 V3.
4. *Gas Free Engineering Program*, NAVSEA S6470-AA-SAF-010.
5. Krivan, Steve P., "Confined Space Entry," *Professional Safety*, September 1982.
6. National Electrical Code, Article 500, from *The National Electrical Code Handbook*. Boston: National Fire Protection Association, 1978, W. I. Summers, editor.
7. *Working in Confined Spaces: Criteria for A Recommended Standard*. Washington, D.C.: U.S. Department of Health, Education, and Welfare, NIOSH. December 1979.

Instruction Key—Unit 8

Safe Entry/Safe Work Permits

Terms

1. Entry permits
2. Hazardous locations
 - a. Class 1—those containing flammable gases or vapors
 - b. Class 2—those containing combustible dusts
 - c. Class 3—those containing easily ignited fibers or flyings

Points for Discussion

1. Designation of a qualified person to authority
 - a. To evaluate and monitor the space
 - b. To determine the classification of entry
 - c. To sign the entry permit
2. Permit design
 - a. Specific confined space to which permit applies
 - b. Date and time of issuance
 - c. Expiration date and time
 - d. Conditions under which a safe condition is certifiable and can be maintained
 - e. Checklist
 - f. Confined space designation

- g. Permit classification

3. Distribution of entry permits
 - a. One copy at main entrance
 - b. One copy posted at all other access areas
4. Recordkeeping
5. Appendices

Questions

1. What are the major responsibilities of the entry authority?
2. Of the three hazardous locations classified in the National Electrical Code, which is the most hazardous and why?

Answers

1. He is responsible for overseeing the evaluation and monitoring of the work environment, for classifying the entry into the space, and for signing and distributing the entry permit.
2. Class 1 locations are the most hazardous because the flammable gases or vapors present create the highest risk of producing explosive or ignitable mixtures.

Appendix A
SAMPLE ENTRY PERMIT

From Working in Confined Spaces:
Criteria for a Recommended Standard
(Washington, DC: NIOSH).

SAMPLE PERMIT CONFINED SPACE ENTRY

Class _____

Location of Work: _____

Description of Work (Trades): _____

Employees Assigned: _____

Entry Date: _____ Entry Time: _____

Outside Contractors: _____

Isolation Checklist:

- Blanking and/or Disconnecting
- Electrical
- Mechanical
- Other

Hazardous Work:

- Burning
- Welding
- Brazing
- Open Flame
- Other

Hazards Expected:

- Corrosive Materials
- Hot Equipment
- Flammable Materials
- Toxic Materials
- Drains Open
- Cleaning (Ex: chemical or water lance)
- Spark Producing Operations
- Spilled Liquids
- Pressure Systems
- Other

Vessel Cleaned:

- Deposits _____
- Method _____
- Inspection _____
- Neutralized with _____

Fire Safety Precautions: _____

Safe Entry Permits

Personal Safety:

Ventilation Requirements

Respirators

Clothing

Head, Hand, and Foot Protection

Shields

Life Lines and Harness

Lighting

Communications

Employee Qualified

Buddy System

Standby Person

Emergency Egress Procedures

Training Sign Off (Supervisor or Qualified Person)

Remarks:

Atmospheric Gas Tests

	Tests Performed	Location	Reading
Example:	(Oxygen)		(19.5%)
Example:	(Flammability)		(Less than 10% LFL)

Remarks:

Test Performed By:

Signature

Time:

Authorizations:

Supervisor:

Prod Supervisor:

Line Supervisor:

Safety Supervisor:

Etc.:

Entry and Emergency Procedures Understood:

Standby Person

Rescue

Telephone

Permit Expires:

Classification:

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Appendix B
EXAMPLE OF VESSEL ENTRY PERMIT

From F.C. Thomas, *et al.*, "Guidelines
for Work in Confined Spaces," *The Med-
ical Bulletin*, Vol. 40, summer 1980.

Safe Entry Permits

EXAMPLE OF A VESSEL ENTRY PERMIT

VESSEL ENTRY PERMIT

Original

This permit covers vessel entry only. A Cold or Hot Work Permit must be issued to cover any work to be done. The permit becomes void at the end of the mechanical work day during which it is issued unless properly endorsed by an authorized employee. Endorsement extends the life of the permit one operating shift only. A permit becomes void if the vessel is not entered within two hours from the time the gas test is completed or if the vessel has not been entered within the last two hours. When vessel entry is completed or ceased for the mechanical day, mechanical department employees will return to the Head Operator of equipment concerned and report present status of the job.

OPERATING UNIT OR AREA	S/R No.
SPECIFIC VESSEL EQUIPMENT OR AREA	TAG NUMBER
WORK TO BE DONE	

EQUIPMENT PREPARATION: Before the vessel is entered a pre-entry gas test must be obtained. It is necessary to certify that the equipment concerned is ready for a gas test. In doing this, certify it is important that all safety factors have been considered and taken care of satisfactorily. To ensure that none of the more important factors are overlooked the following check list of pre-entry preparation considerations should be used as by the Operator as indicated.

	YES	NO	NOT APPLICABLE	OPERATOR'S INITIALS
1. Equipment electrically tagged out				
2. Equipment blocked out (isolated)				
3. Equipment banded				
4. Instrument connections, gauge glasses are disconnected				
5. Equipment washed or steam out free satisfactorily of oil or other combustible materials				
6. Equipment gas freed				
7. Manhole covers, catchpans and other small obstructions satisfactorily covered				
8. Attending equipment and operators' containers satisfactorily removed from vessel's entry point				
9. Do not operate valve tag required				
10. Equipment identification tag required				
11. Equipment acceptance certificate required				

I certify that the above equipment has been properly prepared and is ready for a gas test.

OPERATOR'S SIGNATURE	DATE	TIME	AM/PM
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TYPES OF GAS TESTS REQUIRED AND RESULTS OBTAINED

	AMMONIA (25 ppm max.)	REMARKS
☒ OXYGEN* (19.5% min.)		
☐ CARBON MONOXIDE (50 ppm max.)		
☐ COMBUSTIBLE (400 ppm max.)		
☐ HYDROGEN SULPHIDE (10 ppm max.)		

NOTE: *Required for all permits. Maximum/minimum meter readings are for entry without fresh air mask. Maximum combustible reading for entry with fresh air mask is 10% LEL.

GAS TESTER'S SIGNATURE	DATE	TIME	AM/PM
------------------------	------	------	-------

TOXIC MATERIALS		PRECAUTIONS REQUIRED	
☐ HYDROGEN SULPHIDE	☐ CAA	☐ AVOID SKIN CONTACT	☐ SAFETY BELT
☐ CARBON MONOXIDE	☐ INHIBITOR	☐ PNEUMATIC CLOVES	☐ CHEMICAL GOGGLES
☐ ACID OR CAUSTIC	☐ AMMONIA	☐ RUBBER FOOTWEAR	☐ OR FACE SHIELD
		☐ PVC SUIT	☐ RESPIRATOR
			☐ FRESH AIR MASK
			☐ AIR PURIFYING DEVICES

I certify that the above work has been prepared and is ready for vessel entry.

HEAD OPERATOR'S SIGNATURE	DATE	TIME	AM/PM
---------------------------	------	------	-------

SPECIAL INSTRUCTIONS

ISSUED/ENDORSED BY	POSITION	DATE	TIME	AM/PM
ISSUED				
ENDORSED				
ENDORSED				
ACCEPTED BY (MECH. FOREMAN)				
ISSUED TO (MECH. EMPLOYEE/METAL INSPECTOR)				

ORIGINAL must be retained by person entering Vessel until the work is completed or ceases for the day.

Appendix C
CONFINED ENTRY PERMIT

From: J.A. Jones Construction Corporation.

Safe Entry Permits

CONFINED ENTRY PERMIT

DATE: _____ JOB # _____

LOCATION: _____

NATURE OF WORK: _____

The following protective equipment and precautions have been reviewed with the supervisor in charge of the personnel working (inside) (on) the above tank and are to be initialed as completed prior to entry and/or work:

COMPLIED:	PROTECTIVE EQUIPMENT REQUIRED	YES	NO
_____	1. Safety Belt (harness)	_____	_____
_____	2. Fresh Air Mask (respirator)	_____	_____
_____	3. Rubber Boots & Gloves	_____	_____
_____	4. Fire Extinguisher	_____	_____
_____	5. Blower, Air Mover, Venturi	_____	_____
_____	6. Protective goggles or shield	_____	_____
_____	7. Other: _____	_____	_____
_____	1. Lines to vessel blanked/disconnected	_____	_____
_____	2. Vessel emptied and cleaned	_____	_____
_____	3. Low-voltage light & service lines	_____	_____
_____	4. Explosimeter test (before entry/ constantly)	_____	_____
_____	5. Oxygen test (before entry/ constantly)	_____	_____
_____	6. Switches & Valves Locked & Tagged Out	_____	_____
_____	7. Standby Man Posted Outside	_____	_____

Upon completion of the above noted items, entry may be made.

Tank Entry Authorized: _____

Project Manager/Superintendent/Safety Representative

SIGNED:

STANDBY MAN: _____

MEN ENTERING TANK: _____

NOTE: This form is
to be returned to the
authorizing person upon
completion of work.

Appendix D
PERMIT TO ENTER CONFINED SPACE

From J.A. Jones Construction Corporation.

PERMIT TO ENTER CONFINED SPACE

WO No. _____ Date: _____

Location: _____

Description of Work: _____

PROTECTIVE EQUIPMENT

	Yes	No	Not Apply
1. Safety Line and Harness	☐	☐	☐
2. Goggles/Face Shield	☐	☐	☐
3. Head Protection	☐	☐	☐
4. Protective Clothing	☐	☐	☐
5. Hearing Protection	☐	☐	☐
6. Fire Extinguisher	☐	☐	☐
7. Respiratory Protective Equipment	☐	☐	☐
Type _____			
8. Other _____	☐	☐	☐

QUESTIONS MUST BE ANSWERED

1. Have atmospheric tests been conducted?	☐	☐	☐
2. Document review and approval completed?	☐	☐	☐
3. Lock and tag procedure required?	☐	☐	☐
4. Job safety analysis required?	☐	☐	☐
5. Proper tools and equipment available?	☐	☐	☐
6. Emergency lighting available?	☐	☐	☐
7. Oxygen test - Before entry/constant?	☐	☐	☐
8. Explosimeter test - Before entry/constant?	☐	☐	☐
9. Standby to be posted outside?	☐	☐	☐
10. Employees thoroughly briefed on the hazards and safe methods to do job.	☐	☐	☐

APPROVALS

Superintendent _____

Safety Representative _____

Foreman _____

Standby _____

Note: A copy of this permit shall be posted at the worksite

UNIT 9

HAZARDOUS ATMOSPHERES IN CONFINED WORKSPACES

Often, the really serious accidents in confined workspaces—those resulting in severe injury or illness or in death—can be traced to hazardous atmospheres. Hazardous atmospheres may present safety hazards, or health hazards, or both.

In order to understand the terminology used to describe these hazards, some definitions are in order.

CONFINED WORKSPACE (RESTRICTED-ACCESS)

Confined Workspace (Restricted-Access) can mean one of three things. It can mean a confined space with only one exit. It can mean a confined space with an opening too small for workers to enter walking straight. Or, it can mean a confined space where equipment or structural barriers prevent fast exit or entrance.

RESTRICTED MOBILITY

Restricted Mobility indicates a condition in which a worker is hampered in his work by lack of space or by cumbersome protective equipment.

CONTAMINANT

A *contaminant* is any organic or inorganic substance (such as dust, fumes, mist, vapor, or gas) that can present a hazard.

Contaminants that are lighter or heavier than air will tend to accumulate in the greatest concentrations in the highest or lowest areas, respectively, of a confined workspace.

Of course, a certain amount of diffusion may occur that will disperse the contaminant in varying degrees of concentration throughout the confined space. This is especially true when the concentration of the contaminant is relatively small. However, the *most dangerous* concentrations will occur in the higher or lower positions. Increased temperatures from heated processes or natural causes will increase evaporation and convection rates and cause vapors or gases to diffuse and rise to the upper portions of the space.

When sampling the air in a confined workspace, it is of critical importance that the evaluator understand the nature of the contaminant for which he is sampling. If he does not, sampling instruments may produce readings which do not represent the fullest extent of the hazard in the confined workspace. For instance, because acetylene is lighter than air, it will rise to the upper portion of a confined workspace. If ventilation is not adequate, and if the acetylene gas reaches its explosive limit and a source of ignition, an explosion and fire will result. In an instance such as this, it would be a serious mistake to take a sample of air from the bottom portion of the confined workspace. Only a sample of air taken from the top of the confined workspace would provide accurate information.

A reversal of this situation would occur with argon gas, which is heavier than air. Like all gases heavier than air, argon will seek the lowest levels of an area. It tends to "pool" in places producing high concentrations of the gas which can cause a serious oxygen deficiency. If a confined workspace is to be tested for argon, readings should be taken at the lowest point of the workspace. In addition to pooling, argon may cause an up-scale reading on hot-wire combustible gas instruments, even though it is an inert gas. This is due to thermal conductivity as compared to air.

Ventilation arrangements and the placement of exhaust and make-up air inlets should consider the concentration characteristics of the gases. When contaminants heavier than air are present, exhaust inlets should be located near the bottom of the space with the make-up air inlet at the top of the space. When contaminants are lighter than air, or elevated temperatures are present, the system should be reversed with the exhaust inlet at the top of the space and the make-up air inlet at the bottom of the space. These arrangements will allow the ventilation system to capture and remove the contaminants at the point of greatest concentration and with the least amount of dispersal of the contaminants throughout the space.

Table 9.1
COMMON GASEOUS CONTAMINANTS IN UNDERGROUND CONSTRUCTION

	Possible Sources	Threshold Limit Value	Effect Upon Body	Flammable Limits in Air—% by Volume		Specific Gravity (Air = 1)
				Lower	Upper	
Carbon dioxide	Product of combustion, oxidation, and respiration. May be found vicinity of landfills, sewage lines, sewage treatment plants.	Asphyxiant	Nontoxic. May displace oxygen. Concentrations of more than 5% may cause abnormal respiration.	non-combustible		1.53
Carbon monoxide	Product of combustion. May be found vicinity of internal combustion engines, blasting, or fires.	50 PPM	Combines with hemoglobin in the blood and prevents blood from carrying oxygen to tissues.	12.5	74.0	0.96
Hydrogen sulfide	Product of decomposition of organic sulfur-bearing material. May be found vicinity of swampy areas, landfills, sewage lines, sewage treatment plants, refineries and petroleum product lines.	10 PPM	Paralyzes muscles controlling breathing.	4.0	44.0	1.189
Methane	Occurs in natural gas and as a result of decaying organic material. May be found vicinity of swampy areas, landfills, sewage lines and sewage treatment plants.	Simple Asphyxiant	Nontoxic. May displace oxygen.	5.0	15.0	0.415
Nitrogen dioxide	Product of diesel engines, blasting and high temperature welding.	5 PPM (ceiling value)	Dissolves moisture in lungs, forming nitrous and nitric acids. Only slightly irritating to upper respiratory system. Dangerous concentrations may be encountered without discomfort. Irritation may disappear upon reaching fresh air, but 6—24 hours later throat, bronchi, and lungs suffer congestion and edema.	non-combustible		1.491

From *Professional Safety*, September 1979, p. 27.

Chemical

Any compound mixture or solution in the form of a solid, liquid, or gas is a chemical. A chemical may be hazardous by virtue of its properties other than or in addition to flammability, or by virtue of the properties of compounds that might evolve from hot work or cold work.

Flammable Liquid

A flammable liquid is a liquid with a flash point below 140°F. Flammable liquids are hazardous because of their ease of ignition (low flash point), flammable range, and burning intensity. The degree of danger is determined largely by the flash point of the liquid, the concentration of vapors in the air, and the possibility of a source of ignition at or above a temperature sufficient to cause the mixture to burst into flame. Flammable liquids vaporize and form flammable mixtures when in open containers, when leaks or spills occur, or when heated. Gasoline, ethyl alcohol, benzene, turpentine, and naphtha are examples of flammable liquids. Fluids containing flammable liquids (e.g., paints, varnishes, cleaning solutions) should be considered flammable liquids and classed accordingly.

Combustible Liquid

A combustible liquid has a flash point at or above 140°F and below 200°F. Combustible liquids are usually safe to handle and to work with at normal temperatures, but these liquids should not be heated. Lube oils, kerosene, creosols, benzyl alcohol, cooking oil, mineral spirits, and palm oil are examples of combustible liquids.

Flash Point

The minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid is known as the flash point. Liquids with the lowest flash points are the most hazardous. Flash point temperatures are not constants; they are related to other conditions. For example, the amount of vapor that will accumulate in the air above a volatile liquid depends upon:

1. Vapor pressure or the relative saturation of air with the vapor, or
2. The surface area of the volatile liquid.

AUTO-IGNITION TEMPERATURE

The lowest temperature at which a flammable gas-air or vapor-air mixture will ignite from its own heat source or a contacted heat surface without the necessity of a spark or flame is the auto-ignition

temperature. Vapors and gases will ignite spontaneously at a lower temperature in oxygen than in air. The majority of vapors and gases will not self-ignite in air until they reach temperatures of about 500°F to 900°F.

EXPLOSIVE OR FLAMMABLE LIMITS

Explosive or flammable limits represent the range of gas or vapor concentrations (percent by volume in air) that will burn or explode if any ignition source is present. Concentrations are commonly designated as the lower explosive limit (LEL) and the upper explosive limit (UEL). Below the LEL, the mixture is too lean to burn, and above the UEL the mixture is too rich to burn. LEL and UEL are also known as lower flammable limit (LFL) and upper flammable limit (UFL).

Oxidizing Agents

Oxidizing agents are sources of oxygen, one of the necessary components of a fire. Normal air with its 20% oxygen content is the primary source. However, the chemical makeup of other materials is such that they can supply oxygen, even in the absence of air. When containers of oxidizing materials are damaged during an accident, for example, their contents can mix with the contents of other damaged containers and pose the threat of fire and explosion.

Corrosive Materials

Corrosive materials include acids, acid anhydrides, and alkalis. Such materials often destroy their containers and seep into the atmosphere of a storage area. Some of these materials are volatile; others react violently with moisture. See Appendix A for further discussion of toxic and corrosive agents.

LD. LD is an abbreviation for lethal dose.

Toxicity. The toxicity of a material is not identical with its qualities that make it a health hazard. Toxicity is the material's capacity for producing illness. Hazard is the possibility within a given situation that exposure to a material will cause illness when a specific quantity is used. The key elements to be considered when evaluating a health hazard are:

1. The amount of material required to be in contact with a body cell in order to produce an injury;
2. The duration of contact necessary for injury;
3. The probability that the material will be absorbed or will come in contact with body cells;

4. The rate of generation of airborne contaminants;
5. The control measures in use.

Not all toxic materials are hazardous. The majority of toxic chemicals are safe when packaged in their original shipping containers or contained in a closed system. As long as toxic materials are adequately controlled, they can be used safely.

For example, many solvents, if improperly used, will cause irritation to the eyes, mouth, and throat. They are also intoxicating and can cause blistering of the skin and other forms of dermatitis. Prolonged exposure may cause more serious forms of illness. However, if the solvents are used in a well-ventilated area and the person is provided with protective equipment which prevents the substance from coming in contact with the skin, the solvents can be used without presenting undue hazard.

In this case, certain controls—ventilation and protective equipment—have enabled the person to use the solvent while minimizing the risk of illness. However, it is strongly urged that nontoxic materials be substituted for toxic ones whenever possible.

Acute and Chronic Effects

The toxic action of a substance can be divided into acute and chronic effects:

- *Acute effects* are the result of sudden and severe exposure, during which the substance is rapidly absorbed. Usually, acute effects are related to an accident, which disrupts ordinary processes and controls. For example, sudden exposure to a high concentration of zinc oxide fumes can cause acute poisoning.
- *Chronic effects* involve continued exposure to toxic substances over long periods of time. When the chemical is absorbed more rapidly than the body can eliminate it, accumulation in the body begins. Since the level of contaminant is relatively low, the effects may go unnoticed until the damage has progressed so far as to be irreversible. For example, breathing even low concentrations of carbon monoxide for long periods of time can damage the heart muscles and blood vessels.

THRESHOLD LIMIT VALUE (TLV) AND PERMISSIBLE EXPOSURE LIMIT (PEL)

Threshold limit value (TLV) is a time-weighted average air concentration believed to cause no adverse effects in most workers repeatedly exposed

during the usual workday of seven to eight hours, five days a week, for extended periods of time. There are explicit limits on the magnitude of excursions above the TLV. In some cases, a finite limit or ceiling value is stated which applies to short-term exposure.

Threshold Limit Value, a copyrighted trademark of the American Conference of Governmental Industrial Hygienists, became, by Federal Standards, Permissible Exposure Limit (PEL). PEL's represent the legal maximum level of contaminants in the air of the workplace. For example: The current OSHA standard for hydrogen sulfide is a ceiling level of 20 parts of hydrogen sulfide per million parts of air (ppm) or a maximum allowable peak of 50 ppm for ten minutes once, if no other measurable exposure occurs. NIOSH has recommended that the permissible exposure limit be reduced to 15 mg/m³ (10 ppm) averaged over a 10-minute period, and that work areas in which the concentration of hydrogen sulfide exceeds 70 mg/m³ be evacuated.

Explosive Atmosphere

An atmosphere that contains flammable vapors, gases, or dust in concentrations within their explosive limits is called an explosive atmosphere.

Corrosive Atmosphere

A *corrosive atmosphere* is any atmosphere in which there is a mist, vapor, or dust of a corrosive chemical such as chromic acid, sulfuric acid, caustic soda, etc.

EXTREME-TEMPERATURE ATMOSPHERE

An area too hot to allow normal breathing, necessitating breathing apparatus and insulated clothing, is known as an extreme-temperature atmosphere.

IDLH (IMMEDIATELY DANGEROUS TO LIFE AND HEALTH)

Some concentrations of contaminants are so hazardous that, even when inhaled for very short periods, they can be immediately dangerous to life or health (IDLH). In the case where the concentrations of contaminants are unknown, only self-contained breathing apparatus (SCBA), which provides maximum respiratory protection is to be used. In the case where the concentrations of contaminants are known, the type of respirator used will depend upon the types and the concentrations of the contaminants present: either an SCBA, hose mask with blower, gas mask, or gas mask with special filter may be used as needed.

Oxygen Deficiency

An immediate concern of anyone entering a confined workspace is that the atmosphere may be oxygen-deficient. Oxygen deficiency can occur in any confined workspace. It can kill quickly and without warning. The level of oxygen in a confined workspace may become dangerously low in a relatively short period of time.

Normal fresh air contains 20.8% oxygen. Most safety standards require a minimum oxygen level of 19.5 percent. At this level, a worker probably will not experience discernible physical symptoms. Oxygen levels less than 10 percent may result in rapid decline in physical condition, possibly ending in death.

Many of the indications of oxygen deficiency are mild—may in fact be pleasant (ranging from a slight ringing of the ears to a euphoric state). They are also often attributable to other causes. As well, the oxygen content within a confined space may reach a fatally low concentration in a very short time. By that time, the worker's judgment could be so severely impaired that, with no sense of the danger he is in, he has made no attempt to escape.

Table 9.2 shows the relationship between decreasing levels of oxygen, duration of exposure, and the effects.

Oxygen deficiency may be caused by oxidation of metals, combustion, and displacement by inert gases. Bacterial action is less common, so it is often overlooked. Simple asphyxiants can also create an oxygen deficiency. These physiologically inert substances cause asphyxiation by displacing air and creating an oxygen deficiency. Methane gas is an example of an asphyxiating chemical.

Wet charcoal may be another cause of oxygen deficiency. And finally, fires can consume most or all of the oxygen in a space.

PRECAUTIONS FOR WORKING WITH SOLVENTS

Work involving solvent-type material should be done only when all of the following precautions have been taken.

First, sufficient exhaust ventilation must be provided to keep the concentration of solvent vapors well below ten percent of the LEL at five feet from the source.

If ventilation fails, or if the concentration of solvent vapors rises above or approaches the LEL, work should be stopped and the compartment evacuated until the concentration is well below ten percent of the LEL.

Ventilation should then continue until the compartment is free of explosive vapors. The final determination as to whether the space is free of vapors should be made after the ventilating equipment has been shut off for at least ten minutes.

It should be made certain that exhaust ducts discharge clear of working areas, other ventilation intakes, and sources of possible ignition. Periodic tests will ensure that the exhausted vapors are not accumulating in other areas.

Only explosion-proof lights may be used in the space. Welding, burning, smoking, or any spark-producing equipment should never be allowed within fifty feet of the area.

The use of comparatively large quantities of chlorinated solvents for cleaning up oil and grease should be prohibited. Less toxic high-flash aliphatic solvents or emulsifying-type cleaners should be used for large oil and grease cleanup jobs.

Sufficient forced ventilation to insure safe concentrations of solvent vapor in the workroom should be provided where regular chlorinated solvent processors (such as degreasers) are installed.

Skin contact with chlorinated solvents should be avoided.

Halogenated solvents and refrigerant gases (chlorinated hydrocarbons) should never be allowed to come in contact with an open flame or red-hot metal. Deadly phosgene gas may be formed.

Hazardous Atmosphere Control Methods¹

These steps must be taken to provide protection against toxic, flammable, and oxygen-deficient atmospheres in confined workspaces. They are regulations by many state and federal agencies concerned with construction and mining safety.

The workspace should be ventilated with sufficient quantities of air to sweep contaminants out and maintain oxygen levels of at least 20 percent.

The atmosphere should be tested for the presence of contaminants and oxygen deficiency. When dangerous levels of contaminants or oxygen deficiency are noted, steps should be taken to increase ventilation, eliminate sources of ignition, or provide personal protective equipment, as conditions require.

A team of trained rescuers should be equipped with appropriate respiratory protection and other necessary protective equipment to provide needed assistance in the event of an emergency.

Table 9.2
RELATIONSHIP OF OXYGEN CONCENTRATIONS,
DURATION OF EXPOSURE AND EFFECT

Concentration %	Duration	Effect*
20.9	Indefinite	Usual oxygen content of air.
19.5	not stated	REHD recommended minimum oxygen content for entry without air supplied respirators. Also OSHA standard 29CFR 1910.
18.0	not stated	ANSI Z117.1-1977 definition of oxygen deficient atmospheres.
16.0	not stated	Lowest limit of standards reported in literature.
12—16	seconds to min.	Increased pulse and respiration, impaired judgment, some coordination loss.
10—14	seconds to min.	Disturbed respiration, fatigue, faulty judgments, emotional upset, poor circulation.
6—10	seconds	Nausea, vomiting, inability to move freely, loss of consciousness followed by death.
Below 6	seconds	Convulsions, gasping respiration followed by cessation of breathing, cardiac arrest, death in minutes.

*Effect—Warning properties of low oxygen are inadequate except to trained individuals. Most persons fail to recognize danger until too weak to effect self-rescue. Signs include increased rate of respiration, and circulation, which accelerates onset of more profound effects, including loss of consciousness, irregular heart action and muscle twitching. Unconsciousness and death can be sudden.

From F. C. Thomas et al., "Guidelines for Confined Spaces," in *The Medical Bulletin*, summer issue, p. 9.

Vapor Disposal

Special consideration should be given to disposal of flammable vapors.

Gas vapor removal and ventilation of the space should be conducted as expeditiously as possible.

Hazardous gases and vapors may be present outside as well as inside the space.

Vapors and gases within the flammable range are potentially hazardous when mixed with air. Heat

applied to residues in tanks will produce more vapors to be disposed of, which will in turn increase the hazard on the outside of the space.

Combustible gas indicator tests outside the confined workspace are of major importance in determining safety of vapor disposal.

NOTE: Heavy vapors may collect in depressions or locations below ground level. Vapors may remain intact in layers and travel considerable distances

to a source of ignition. Flames have been known to return to the vapor source, causing a fire or explosion.

NOTE: Any potential source of ignition in the way of the vapor-air mixture's exhaust stream should be extinguished, made inoperative, or removed.

Forced Ventilation

Forced ventilation may be required in many cases where repair work is to be done inside a tank.

Where fumes develop from welding or other repair work, mechanical air motors should be used or the workmen should wear fresh air hose masks. On a large tank, a door sheet or sheets may be removed for ventilation after the tank has been cleared of gas. The opening can also be used to expedite removal of sediment and to improve the lighting within the tank.

If a confined space has been closed for some time, there may be a deficiency of oxygen due to rusting (oxidation) of the metal of the tank. In that case, no one should enter without a supplied air mask or, for a relatively brief period, a self-contained or self-generating breathing apparatus.

Hydrochloric Acid Cleaning Precautions

Personal contact with hydrochloric acid must be avoided. As a safety measure, a supply of fresh water and sodium bicarbonate should be instantly available in areas where the acid is being used or where it is being prepared or mixed. That way, any acid that gets on the skin can be thoroughly washed and neutralized. If the acid gets in the eyes, it must be flushed out with an abundance of clean fresh water with an eyewash fountain.

NOTE: Always obtain medical attention if acid gets into the eyes, ears, nose, or mouth. If acid should soak any portion of the clothing or shoes, immediately remove the clothing.

Rubber or acid-resistant boots, gloves, aprons, and hats must be worn by all workers handling acid or acid containers. In addition, goggles and face shields must be worn by workers mixing chemicals.

A full-face filter type or air line respirator must be worn when mixing hydrochloric acid.

NOTE: Smoking, burning, or hot work must not be permitted in the area of the acid, or near the vent discharge line during the use of hydrochloric acid. Signs must be posted at all areas where the acid is used and at all areas where gases are present as a result of the acid cleaning or mixing.

Labeling Hazardous Materials

Information concerning all hazardous materials used on the job site should be available to supervisors and workers alike. Proper labeling is a fundamental part of a safe and effective operation. Labeling has two principal functions: (1) it identifies what the material is and where it came from and (2) it provides precautionary information for safe handling of all chemicals that present a substantial hazard.

Purchased materials should be labeled with either the chemical or the common name of the material, the name of the manufacturer, and a lot number. If the chemical is flammable, a flash point may be shown on the label accompanied by a precaution regarding fire hazard. If the material is corrosive, toxic, reactive, or unstable, other precautionary information is usually shown.

Absence of a precaution on the label does not necessarily mean that there is no hazard. Some manufacturers are not diligent in providing such information; nor are some purchasing agents conscientious in channeling the information to field supervisors.

Absence of labels can be very dangerous. When hazardous materials are found in containers with no identifying label or with a label illegible from contact with chemicals, such containers must be removed until they can be identified and labeled. If such identification cannot be made, the material should be disposed of. Liability suits are often based on inadequate labeling of a material involved in an accident. Good labeling practice helps protect the contractor from such litigation.

Regulations

Labeling is now required by the Federal Hazardous Substance Act on all flammable, corrosive, reactive, toxic, or radioactive substances intended for non-industrial use.

The Occupational Safety and Health Act has a general duty clause requiring an employer to provide a safe place of employment. Unlabeled or inadequately labeled hazardous materials could be construed as a violation of this act.

The National Fire Protection Association, in its NFPA 704M, Standard System for the Identification of the Fire Hazards of Materials, has developed a popular hazardous materials identification system. The NFPA System uses a diamond-shaped diagram divided into four parts (see Figure 9.1).

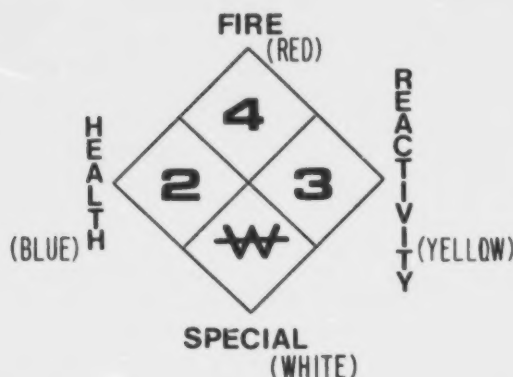


Figure 9.1 Reprinted with permission from NFPA 704-1980, *Standard System for the Identification of the Fire Hazards of Materials*, Copyright© 1980, National Fire Protection Association, Quincy, Massachusetts 02269. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

The top segment indicates the flammability hazard and is colored red. The segment to the left of the fire hazard indicates the health hazard of the material and is colored blue. The segment to the right of the fire hazard indicates the reactivity hazard and is colored yellow. The bottom segment is reserved to identify special information of which the user should be aware. For example, a W with a line drawn through it ($\overline{W}$) indicates unusual reactivity with water. Oxidizing chemicals are identified by an OXY in the bottom segment, and radiation hazards are identified with the radiation symbol.

The hazard rating for each category of hazard pertaining to a given material is indicated by a number in the appropriate segment. The number scale ranges from 0 to 4, with materials designated as 0 presenting little or no hazard and materials designated as 4 presenting extreme hazard (see Table 9.3). It should be noted that the health hazard designations refer only to the immediate acute effects of exposure to the chemical. The chronic long-term health effects are not taken into account.

The NFPA hazard symbol is a method by which the worker can see at a glance the dangers presented by a particular substance. It helps to ensure proper storage and use of chemicals and solvents. Some manufacturers include the diagram on their labels. In order to make a hazard symbol when the

manufacturer has not provided one, refer to label statements and detailed Material Safety Data Sheets (see Appendices B and C).

Perhaps the major limitation to the NFPA system is that it does not identify the specific chemical involved, but only the hazards it represents.

The National Institute for Occupational Safety and Health (NIOSH) has a system which incorporates the NFPA Standard while being more specific (providing the trade or chemical name) and more detailed. In a criteria document entitled *An Identification System for Occupational Hazardous Materials*, NIOSH recommends that the label contain the following:

1. The trade name or chemical name of the product;
2. A hazard symbol consisting of three rectangles containing brief indications of a relative health hazard, fire hazard, and reactivity hazard;
3. Appropriate statements on the nature of the hazard;
4. Appropriate action statements;
5. Emergency action and first aid statements;
6. Cleanup and disposal statements where appropriate.

Examination of each part of the recommendation shows that the first part provides what the NFPA system does not, the trade or chemical name of the product. The second part incorporates the NFPA hazard symbol just discussed.

The remainder of the recommendations are label statements. Such statements convey more information than the hazard symbol and less information than the Material Safety Data Sheet which is also part of the NIOSH criteria documents. Appendix B of this unit contains details about Recommendations 3 through 6:

1. Label statements on the
 - a. nature of the hazard (health, fire, and reactivity)
 - b. action necessary to protect against the hazard.
2. Label statements concerning first aid.
3. Label statements concerning cleanup and disposal.

The NIOSH document also contains a Material Safety Data Sheet, a form by which manufacturers transmit hazard information to users. It contains relevant information about the physical and toxicological properties of the chemical. Labels generally list only the major components of chemical reagents or solvent mixtures. Therefore, the data sheet must be relied upon for information

Table 9.3

NFPA HAZARD CODING SYSTEM

Identification of Health Hazard Color Code: BLUE		Identification of Flammability Color Code: RED		Identification of Reactivity (Stability) Color Code: YELLOW	
Type of Possible Injury		Susceptibility of Materials to Burning		Susceptibility to Release of Energy	
Signal		Signal		Signal	
4	Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given.	4	Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or which are readily dispersed in air and which will burn readily.	4	Materials which in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.
3	Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given.	3	Liquids and solids that can be ignited under almost all ambient temperature conditions.	3	Materials which in themselves are capable of detonation or explosive reaction but require a strong initiating source or which must be heated under confinement before initiation or which react explosively with water.
2	Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given.	2	Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.	2	Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate. Also materials which may react violently with water or which may form potentially explosive mixtures with water.
1	Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given.	1	Materials that must be preheated before ignition can occur.	1	Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.
0	Materials which on exposure under fire conditions would offer no hazard beyond that of ordinary combustible material.	0	Materials that will not burn.	0	Materials which in themselves are normally stable, even under fire exposure conditions, and which are not reactive with water.

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about chemical components which, though minor, may be toxic or dangerous.

Most manufacturers and suppliers have developed information sheets similar to the NIOSH form. At the time that hazardous materials are purchased, the manufacturer should be asked to furnish such toxicity and hazard information.

Other Label Information

In addition to the six NIOSH recommendations, labels should contain:

1. The manufacturer's name and the lot number of the chemical;
2. The age of the material.

The first item is important because manufacturers sometimes need to recall batches of chemicals. When the manufacturer's name is on the label, the substance under question can be located quickly. The second item is important because some chemicals become unstable or ineffective with age.

It may not be practical to put all the desired information on the label, especially if the container is small. Good judgment must be employed in selecting what information should appear. The most essential item is the chemical or product name, which should never be omitted. Figure 9.2 is a sample label which includes the information discussed in this section. Appendix C illustrates data sheets provided by Associated General Contractors of America (AGC) and OSHA.

DISPOSAL OF HAZARDOUS MATERIALS

The NIOSH criteria document deals in its last section with the disposal of hazardous materials. Toxic and hazardous wastes can be both difficult and expensive to get rid of.

The disposal of hazardous materials is strictly regulated by law in many states. When a contractor orders the pouring of hazardous materials down a drain or onto the ground, he may be violating applicable state or municipal laws. Municipal, state, and federal laws all regulate the discharge of toxic and hazardous materials into sewage systems, receiving waters and the atmosphere.

CONCLUSION

In this unit we have introduced terms that apply to hazardous materials in confined workspaces. We have described factors contributing to hazardous concentrations. We have discussed various precautionary and control methods for working with hazardous materials. And we have provided useful information regarding federal regulations that pertain to hazardous materials.

Notes

1. Adapted from J.T. Patterson, "Hazardous Atmospheres in Underground Construction" in *Professional Safety*, September 1979, p.28.

References

1. *Maintaining Facilities and Operations: Instructor's Resource Guide* (National Institute for Occupational Safety and Health, Division of Training and Manpower Development, September 1979) Unit IV, Section II, Hazardous Materials—Use and Control.
2. Naval Ships' Technical Manual (NAVSEA S9086-CH-STM-030/Ch-974 Volume 3, "Gas Free Engineering."
3. *Safety and Health for Industrial/Vocational Education for Supervisors and Instructors* (Cincinnati: National Institute for Occupational Safety and Health) Unit 13, "Health Hazards."

Hazardous Atmospheres in Confined Workspaces

CHEMICAL NAME _____

FORMULA _____

FLASH POINT _____

KINDS OF
HAZARDS

CORROSIVE TO SKIN AND EYES _____
TOXIC BY INGESTION _____
TOXIC BY INHALATION _____
TOXIC BY SKIN CONTACT _____

FLAMMABLE _____
REACTIVE WITH WATER _____
UNSTABLE _____
RADIOACTIVE _____

SEVERITY OF
HAZARDS

HEALTH	0	1	2	3	4
FIRE	0	1	2	3	4
REACTIVITY	0	1	2	3	4
SPECIFIC	_____				

EMERGENCY
TREATMENT _____

SUPPLIER _____

DATE _____

PREPARED _____

PURCHASED _____

RECEIVED _____

USAGE _____

OTHER
INFORMATION _____

Figure 9.2. From *Safety in the School Science Laboratory*, NIOSH, August 1977, P. W-8-35.

Instruction Key—Unit 9

Hazardous Atmospheres in Confined Workspaces

Terms

1. Restricted-access confined workspace: one with few and small openings
2. Restricted mobility: cramped space or cumbersome protective equipment
3. Contaminant: any substance that may present a hazard
4. Chemical: any solution that may be hazardous either in and of itself or in conjunction with certain other substances or work processes
5. Flammable liquid: flash point below 100°F
6. Combustible liquid: flash point at or above 100°F
7. Flash point: the minimum temperature at which a liquid may form an ignitable mixture
8. Auto-ignition temperature: the lowest temperature at which a flammable substance will ignite from its own heat source
9. Explosive or flammable limits: the range of gas or vapor concentrations that will burn or explode if any ignition source is present
10. Threshold limit value and permissible explosive limit: a time-weighted average air concentration believed safe at normal work week exposures
11. IDLH (immediately dangerous to life and health): concentrations of contaminants that may be dangerous even during very short exposures
12. Simple asphyxiant: a gas that displaces oxygen in the atmosphere
13. Chemical asphyxiant: a material that renders the body incapable of using the required amount of oxygen
14. Cold work: any job process that does not require heat
15. Hot work: any job process that requires heat
16. Supply ventilation: moving fresh air into a contaminated space
17. Local exhaust ventilation: removing contaminated air from its point of origin
18. Oxidizing agents: sources of oxygen
19. Corrosive materials: acids and alkalies that may destroy their containers and seep into the atmosphere
20. LD: lethal dose
21. Toxicity: the capacity of a substance to produce illness
22. Acute effects: resulting from sudden and severe exposure

23. Chronic effects: resulting from continued exposure over long periods

Points for Discussion

1. Definitions
2. Factors contributing to hazardous concentrations
 - a. Carbon profile
 - b. Release of burnable, volatile gases and vapors
3. Inert-gas metal-arc welding
 - a. Hazards
 - b. Precautions
4. Precautions for working with solvents
 - a. Ventilation
 - b. Explosion-proof equipment
 - c. Prohibiting spark-producing activities
 - d. Isolating solvents from open flames or red-hot metals
5. Hazardous atmosphere control methods
 - a. Ventilation
 - b. Testing and monitoring
 - c. Rescue procedures and equipment
 - d. Vapor disposal
6. Hydrochloric acid cleaning precautions
 - a. Avoidance of personal contact
 - b. Fresh water and sodium bicarbonate available to neutralize spills
 - c. Proper personal protective equipment
7. Labeling hazardous materials
 - a. Functions
 - b. Absent labels
8. Regulations
 - a. NFPA hazard symbol
 - b. NIOSH criteria document recommendations
 - c. Other label information
 - d. Disposal of hazardous material
9. Appendices

Questions

1. What is a restricted-access confined workspace?
2. Why would it be a serious mistake to test for acetylene at the bottom of a confined workspace?
3. What is the difference between a flammable and a combustible liquid? Which is the more hazardous to work with?
4. What causes oxygen deficiency?

5. Explain the difference between the toxicity and the hazard of a material.
6. What are the two major functions of labeling of hazardous materials?

Answers

1. It may be a confined space with only one exit, with an opening too small for workers to enter walking straight, or with equipment or structural barriers that prevent fast exit or entrance.
2. Acetylene is lighter than air, which means that it will tend to concentrate near the top of the confined space, not the bottom.
3. A flammable liquid has a flash point below

100°F; a combustible liquid has a flash point at or above 140°F. The flammable liquid is obviously the more hazardous, therefore, since it will ignite at lower temperatures.

4. It may be caused by oxidation of metals, combustion, displacement by inert gases or, less commonly, by bacterial action.
5. The toxicity of the material is its capacity for producing illness. The hazard is the possibility within a given situation that exposure to the material will produce illness.
6. It identifies what the material is and where it came from, and it provides precautionary information for safe handling of all chemicals that present a substantial hazard.

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Appendix A
EXAMPLES OF TOXIC AND CORROSIVE AGENTS

Adapted from *Safety and Health for Industrial/Vocational Education* (Cincinnati: National Institute for Occupational Safety and Health) July 1981. Unit 13, "Health Hazards."

EXAMPLES OF TOXIC AND CORROSIVE AGENTS

Aluminum—In welding and cutting operations, aluminum is a major component of metals and filler metals. The inhalation of aluminum dust or its compounds, including aluminum oxide fumes, is not known to have any adverse health effects.

Antimony—Antimony is used as an alloying metal in many specialty metals. Antimony and its compounds irritate the skin and mucous membranes. Skin contact with antimony can result in a dermatitis which begins as an inflammation of the hair follicles and progresses through pus formation and sloughing to leave a scar. Symptoms of excessive exposure to airborne antimony are a metallic taste in the mouth, vomiting, loss of appetite, and general stomach distress. Chronic exposure reduces white blood cells and causes liver damage.

Argon—Used as a purging agent for welding, a colorless, inert gas which is classified as a simple asphyxiant gas. Although argon has no specific toxic effect, it acts by excluding oxygen from the lungs. At a concentration of 33% in the air, argon begins to produce appreciable symptoms. At 50%, marked symptoms can be produced. A concentration of 75% is fatal in a matter of minutes. The first symptoms produced are rapid respirations and "air hunger," that is, the sensation of being uncomfortably short of breath. Mental alertness is diminished and muscular coordination impaired. Later, judgment becomes faulty and all sensations are depressed. As the asphyxia progresses, there may be nausea and vomiting, prostration and loss of consciousness, and finally convulsions, deep coma, and death.

Aromatic Naphtha—Aromatic naphtha (or coal tar naphtha) contains a high proportion of aromatic hydrocarbons and has toxicity and flammability properties comparable to the pure aromatics for which it is used as a substitute in many formulations.

Arsenic—Arsenic may be encountered in welding and cutting operations as a component of various alloys, where it gives increased heat resistance and hardness. Welding or cutting on metals that are painted with arsenic compounds can also be hazardous. Arsenic is a poison that accumulates in the body. It is deposited in many bodily tissues, especially in the liver and kidneys. Fumes and dust produce inflammation of mucous membrane surfaces, irritation of the eyes and exposed skin, and a husky

voice and cough. Because the effects of arsenic may not appear for weeks, months, or even years after exposure, workers should be protected from all contact. Because serious skin irritation results from contact with rubber in the presence of arsenic, respirators used for protection should not be made of rubber.

Asbestos—Asbestos may be found in many locations. Hand- and power-operated tools may produce or release asbestos fibers; asbestos pads may be used for welding and soldering; personal protective equipment (aprons, gloves, etc.) may contain asbestos; workers repairing machine linings may be exposed to asbestos. Once asbestos fibers are inhaled, they may remain trapped in the lung, where the body tries to isolate them by producing scar tissue. Long-term exposure to high concentrations of asbestos fibers causes asbestosis, a disease of the lungs, and is thought to cause cancer. The main symptom of asbestosis is shortness of breath. Engineering controls include isolation, enclosure, exhaust ventilation, and dust collection. Respirators and special clothing may also be necessary.

Benzene—Benzene (sometimes called benzol, phenyl hydride, coal naphtha) is classified as a flammable liquid as well as a carcinogen. Inhalation of high concentrations can affect the central nervous system. High concentrations of benzene are irritating to the mucous membranes of the eyes, nose, and respiratory tract. Exposure to benzene can also lead to the development of leukemia. Its vapors can form explosive mixtures and burn with a smoky flame. Because it is one of the two or three most dangerous organic solvents in commercial use, use of benzene should be avoided whenever possible. It can be replaced with toluene in most lacquers, synthetic rubber solutions, and paint removers. Benzene should not be confused with benzine, a petroleum distillate.

Beryllium—Beryllium and its compounds are highly toxic, causing serious chronic or fatal lung diseases and dermatitis. Concentration of beryllium particulate matter in air considered safe is so low that the safe working level is, for all practical purposes, zero.

Any operations involving beryllium and its alloys or compounds likely to generate dust or fumes must be meticulously controlled and frequently monitored.

Butyl Alcohol—Butyl alcohol (butanol) is used as a lacquer solvent. Its vapors are very irritating to the eye, even at concentrations below its threshold limit value, and are appreciably more toxic than methyl or ethyl alcohol. Butanol can affect the liver and the blood.

Cadmium—Cadmium may be found as a coating on metals in welding areas. Cadmium is used frequently as a rust-preventive coating on steel and also as an alloy. Cadmium-plated or alloy steel may look like zinc-coated steel. Cadmium oxide (CdO), the brownish-yellow fume produced when cutting cadmium-containing metals, can be extremely hazardous.

Excessive cadmium oxide exposure causes no marked initial discomfort. However, acute symptoms occur a few hours later. These symptoms include dry cough, irritation of the throat, and tightness of the chest. Extreme difficulty in breathing, chest pains, and possible death from pulmonary edema (fluid in the air spaces of the lungs) may follow. Long-term exposure to low levels of cadmium in the air can result in kidney damage and emphysema. Adequate ventilation must be provided. Respirators and protective clothing offer additional protection.

Carbon Monoxide—Carbon monoxide is a gas usually formed by the incomplete combustion of various fuels. It is commonly found in automobile engine exhaust. Portable gas-filled heaters also produce carbon monoxide, as do internal combustion engines and improperly maintained or adjusted burners and flues. Carbon monoxide is odorless and colorless and cannot be detected by the senses. Common symptoms of overexposure include pounding of the heart, a dull headache, flakes before the eyes, dizziness, ringing in the ears, and nausea.

Carbon Tetrachloride—Carbon tetrachloride is one of the most toxic solvents; it has caused more deaths and injuries than any of the others. Use of carbon tetrachloride is prohibited for any purpose.

Chromium—Chromium is the primary alloying agent in stainless steel. Some chromium compounds are strong oxidizing agents and are extremely toxic and irritating to the skin, eyes, and mucous membranes. Workers exposed to chromium compounds have a death rate from lung cancer twenty-nine times that of the average population. Although welding under normal conditions will not produce hazardous concentrations of chromium compounds, welding of stainless steel should be carried out with adequate ventilation.

Chlorinated Hydrocarbon Solvents—Various chlorinated hydrocarbons (e.g., trichloroethylene, perchloroethylene, and carbon tetrachloride) are used in degreasing and other cleaning operations. They may injure the liver, cause dermatitis, and depress the central nervous system. Skin contact should be avoided. A respirator should be used so that the vapors will not be inhaled. In welding and cutting operations, the heat and ultraviolet radiation from the electric arc will decompose the vapors of these solvents and form highly toxic and irritating phosgene gas (see Phosgene).

Cobalt—Cobalt appears as an alloying agent in high-strength, high-temperature alloys. Cobalt produces an allergic skin irritation, and inhalation of cobalt fumes can cause shortness of breath and coughing. A common allergic response to cobalt dust is cobalt pneumoconiosis, which can be fatal. Because many workers become sensitized to cobalt at concentrations lower than the legal limit, engineering controls to avoid exposure are necessary.

Esters—As a class, esters have a low order of toxicity but do produce narcosis and are irritating to the respiratory tract. The principal esters, such as ethyl acetate, butyl acetate, and amyl acetate, are used primarily as lacquer solvents. The esters are all classed as flammable liquids with ethyl acetate being the most flammable of the three.

Ethyl Alcohol—Ethyl alcohol (ethanol) is also used as a general solvent. The effects of ethanol ingestion are well known.

Epoxy Compounds—Epoxy resins and catalysts are toxic. Severe skin irritations and allergic reactions have been noted in some individuals. Safety precautions must be followed to avoid inhalation or direct skin contact.

Avoid contact with skin and eyes during application and grinding operations. (Use protective clothing and skin creams, gloves, and goggles with face shield.) Avoid inhaling fumes and dust, either by providing exhaust ventilation or by wearing organic vapor respirators. Avoid spilling. Promptly clean up all drippings, waste, and deposits on tools. Wash all protective clothing and equipment if contaminated. Place waste matter in covered waste cans. Keep chemical containers clearly labeled and tightly covered when not in use. Any individual worker showing a sensitivity to the compounds should be removed immediately from the area and referred to the medical department.

Epoxy Resins—Materials which should be regarded as hazardous include wet or uncured epoxy resins and the chemicals used to harden, thin, strengthen, or make the resin flexible. Dermatitis can result from handling epoxy resins and the chemicals used to manufacture them or from sanding or polishing epoxy surfaces. The use of impervious plastic gloves and similar protection over other skin areas can help prevent this condition. Some of the symptoms of dermatitis include redness, itching, swelling, and blisters. Oozing, crusting, and scaling of the skin may also occur.

Respiratory irritation, headache, nausea, intestinal upsets, and other conditions may result from breathing vapors or dust from the various epoxy manufacturing processes. The eyes may also be affected by vapors or by direct contact.

Fluorides—Fluoride compounds are found in the coatings of several types of fluxes used in welding. Exposure to these fluxes may irritate the eyes, nose, and throat and may produce painful skin burns. Repeated exposure over a long period to high concentrations of fluorides in the air may cause pulmonary edema (fluid in the lungs) and bone damage. Prolonged exposure to fluoride dusts and fumes also may cause acute systemic poisoning.

Foamed plastics—Some of the numerous applications for foamed-in-place polyurethane plastics are filling voids and providing thermal insulation. Many such applications require that the operations be performed in confined spaces. The foaming agent, toluene diisocyanate (TDI), is highly irritating even in very small concentrations.

Workers should not remain in areas with comparatively high concentrations of TDI fumes. Its odor is practically undetectable at its very low threshold limit value, but it is extremely irritating to the eyes and the respiratory system. Precautions should be taken in operations involving both mixing and applying foamed-in-place plastics, including providing local exhaust ventilation, wearing air-supplied respirators, wearing chemical goggles and impervious gloves and aprons where splash or contact with the skin or eyes is possible, and providing adequate ventilation or respiratory protection when welding or other heating operations are likely to burn any foamed plastic material already in place.

Freon—Used as a refrigerant and as a purging agent. It is a colorless, almost odorless gas, which is nonflammable and only slightly toxic. Freons

exposed to flames or heated surfaces will decompose to form highly toxic fumes of phosgene and fluorides. Chemically, freons are fluorinated hydrocarbons. Should freon gas escape into confined spaces, it may produce an oxygen-deficient atmosphere.

Halogenated Hydrocarbons—Solvents in the halogenated hydrocarbon class are usually considered nonflammable. For this reason, and also because of their high volatility and generally good solvent action on a variety of organic compounds, halogenated hydrocarbon solvents are widely used for removal of oil and grease, paint stripping, and general cleaning.

All halogenated hydrocarbon solvents are toxic and narcotic. They may produce deep anesthesia, even death, under prolonged exposure to excessive concentrations. Some of these solvents are also poisonous.

Hydrochloric Acid—Hydrochloric acid is a corrosive substance used in metal work as a flux for soldering galvanized iron. It is also used for electroplating and pickling.

Inhalation of excessive concentrations of hydrochloric acid mist results in irritation of the upper respiratory tract, usually limited to inflammation of the nose, throat, and larynx. Fortunately, the pungent, irritating odor gives adequate forewarning of hazard. Ingestion of the acid causes burning of the mucous membranes of the mouth, esophagus, and stomach. The major protection should be local exhaust ventilation and enclosure of processes.

Aqueous solutions of hydrochloric acid cause severe skin burns unless promptly removed with water. Dermatitis may ensue upon repeated contact of the skin with diluted solutions of the acid. Protective clothing can prevent contact with the skin, and protective creams can prevent irritation of exposed skin. Prolonged contact with the eyes may result in permanent visual impairment or total loss of sight.

There is no conclusive evidence that hydrochloric acid presents chronic systemic health hazards. Hydrochloric acid solutions are not flammable. However, solutions of hydrochloric acid attack most metals, evolving hydrogen, which may form explosive mixtures with air.

Hydrochloric acid solutions must be stored in glass or in rubber-lined containers. These containers should not be stored with or near oxidizing agents,

particularly nitric acid and chlorates, nor highly flammable substances. Because of the highly corrosive action on metals, the areas should be well ventilated. Whenever hydrochloric acid is spilled, the area should be washed immediately with a large amount of water. Lime may be used to neutralize spilled acid on concrete, wood, or other reactive or absorbing materials.

Hydrogen Sulfide—Hydrogen sulfide is a systemic poison, causing respiratory paralysis and the resulting asphyxia at high concentrations. It is also irritating to the eyes and the respiratory tract at low concentrations. Other effects of high concentrations include coma and/or convulsions, and acute conjunctivitis; at low concentrations, the effects include headache, fatigue, irritability, insomnia, gastrointestinal disturbances, bronchitis, and pneumonitis. Ventilation, respirators, and other types of personal protective equipment may all be indicated in areas where hydrogen sulfide is present.

Industrial Ethanol—Industrial ethanol is denatured to render it unpalatable; its vapors are of a low order of toxicity and inhalation produces the same symptoms as those produced by ingestion.

Iron Oxide—During the welding of steel, iron oxide fumes arise from both the base metal and the electrode. The primary acute effect of this exposure is irritation of nasal passages, throat, and lungs. Although long-term exposure to iron oxide fumes may result in iron pigmentation of the lungs, most authorities agree that these iron deposits in the lungs are not dangerous.

Ketones—Ketones are general-purpose solvents for organic materials and are used as solvents in some paint, enamel, varnish, lacquer, and other organic coating formulations. Acetone, methyl ethyl ketone, and methyl isobutyl ketone are the most widely used ketones. All are classed as flammable liquids, acetone being the most highly flammable of the group. Vapors of ketones have fairly strong narcotic effects and are irritating to the respiratory tract.

Lead—Lead was one of the first industrial materials to be recognized as a serious health hazard. The welding and cutting of lead-bearing alloys or metals whose surfaces have been painted with lead-based paint can generate lead oxide fumes. Inhalation and ingestion of lead oxide fumes and other lead compounds will cause lead poisoning. Symptoms include a metallic taste in the mouth, loss of appetite, nausea, abdominal cramps, and insomnia. In time ane-

mia and a general weakness, chiefly in the muscles of the wrists, develop. Prevention of lead poisoning is almost entirely a matter of good housekeeping and dust control. Ventilation is very important.

Lime—To name but a few of its many uses, lime (quick lime, caustic lime, calcium oxide) is found as a binding material in building materials, a dehydrating agent, a flux in steel manufacturing, and in the manufacture of glass and paper. It is a caustic and can rapidly burn the skin, eyes, and upper airways on contact. Inhaling calcium oxide dust can cause chemical pneumonia. If pulverized lime is moistened, it forms calcium hydroxide, which generates heat as well as carbon monoxide and carbon dioxide. Flammable or combustible materials must not be stored near pulverized lime, as they may be ignited from the heat produced.

Workers must wear goggles and gloves when handling lime. Eye wash and emergency shower facilities must be available in the immediate area. "Hydrated pulverized lime" may be substituted for pulverized lime, as it is not heat-reactive and is therefore less of a fire hazard.

Magnesium—Magnesium and magnesium-aluminum alloys, both found as alloys in steel, are used in tool-making. Welding and cutting on magnesium-containing metals produce magnesium oxide fumes. Inhalation of these fumes can irritate the eyes, nose, and throat and cause metal fume fever (see Zinc).

Manganese—Manganese fumes, released near reduction furnaces and from manganese-coated welding rods, can cause metal fume fever. In most cases, the concentrations of manganese dioxide fumes generated during welding are not hazardous. Nevertheless, cases of manganese poisoning have been reported. Manganism is a severely crippling, permanently disabling disease of the nervous system that closely resembles Parkinson's disease. Early symptoms are weakness, instability, difficulty in walking, and monotonous intermittent speech. To avoid the hazards of manganese fumes, welding operations must be well ventilated.

Mercury—Mercury compounds are used to coat metals to prevent rust. Under the intense heat of the arc or gas flame, mercury vapors are produced. Exposure to these vapors may cause stomach pain, diarrhea, kidney damage, or respiratory failure. Long-term exposure may produce tumors, emotional instability, and hearing damage.

Methyl Alcohol—Methyl alcohol (methanol or wood alcohol) is used as a general solvent, and is found in some varnishes, lacquers, shellacs, and paint removers. It is also used as a nonpermanent antifreeze water additive. Compared to other solvents, the vapors of methyl alcohol are not highly toxic. However, ingestion of methanol can be fatal: for this reason it is rated as a poison. Because of the probability of mistakenly consuming methyl alcohol for the desired effects of ethyl alcohol, containers should be conspicuously marked with POISON labels.

Methyl Chloroform—Although methyl chloroform is considerably less toxic than carbon tetrachloride and is prescribed as a substitute, it is toxic, and should be handled according to precautions generally applied to chlorinated hydrocarbons. Because of the corrosive action on metals, particularly on aluminum, most methyl chloroform formulations contain an inhibitor which in itself is flammable. After about 90 percent evaporation of the inhibited solvent, the residue contains a high percentage of flammable inhibitor.

Nitrogen Oxides, Nitrogen Dioxide, and Nitric Acid—Nitrogen oxides are used in the pickling and etching of metals. The high temperatures used in processes such as gas and electric arc welding—especially in poorly ventilated areas—can oxidize the nitrogen in the air into the various nitrogen oxides. Exposure may occur during jewelry manufacture, brazing, lithographing, metal cleaning, glass blowing, and electroplating. Nitrogen oxides also occur in garages from automobile exhaust.

The nitrogen oxides are extremely irritating to the eyes and upper respiratory tract. Though exposure to concentrations above the threshold limit causes cough and immediate chest pain, lower concentrations can be inhaled without great discomfort. There may be only mild signs of bronchial irritation, followed by a five- to twelve-hour symptom-free period. During this period, the nitrogen oxides have changed into nitrogen dioxide, and the nitrogen dioxide has reacted with the watery atmosphere of the respiratory tract and air sacs to produce nitric acid. The nitric acid burns the lungs and air sacs.

As a response to the burning, the injured tissue pours out fluid from the bloodstream. If this fluid accumulates in the lungs, it interferes with oxygen exchange; the victim may suffocate as a result of

pulmonary edema. Even if the victim recovers, he may suffer permanent damage to the small air tubes and sacs, resulting in frequent lung infection, chronic cough, and shortness of breath. Repeated low-level exposures probably cause chronic bronchitis.

Nitric acid is both a product and a by-product. A corrosive, it may be used for pickling and etching metals. Gaseous oxides are formed when nitric acid comes in contact with certain metals—such as copper, brass, or zinc—or with certain organic materials—such as wood, sawdust, cloth, and paper. These oxides are also present in high concentrations during various processes involving the use of nitric acid. Both nitric acid vapors and the gaseous oxides can destroy tissue on contact by direct chemical action.

Severe and deep burns may be produced by skin contact with either the acid or the concentrated vapor. The eyes are very susceptible to injury, and immediate severe damage, possibly of a permanent nature, can result from contact.

Nitric acid is a nonflammable substance. However, it is a strong oxidizing agent. It reacts vigorously with most metals and may cause spontaneous ignition when in contact with organic materials such as sawdust, wood scraps, shavings, and paper. The acid may cause an explosion when in contact with certain easily oxidized chemicals. Under certain circumstances, both the acid and the vapor will react with wood cellulose, cotton, and similar organic materials to increase their flammability.

Nitric acid should be stored in its original container. It should be kept well away from combustible materials such as turpentine, carbides, hydrogen sulfide, and metallic powders. Nitric acid is corrosive to most metals and most organic materials.

The immediate removal of the acid is essential in the case of accidental spills. A large amount of water should be used if the floors are of wood or if other combustible materials are present.

Organic Solvents—The variety of solvents used in compounds or formulations such as paints, adhesives, rubber and plastic materials, and in degreasing solutions. Under certain conditions, all organic solvents are toxic in varying degrees and, with the exception of chlorinated solvents, they are flammable. Organic solvents encountered on the jobsite may be broadly classified according to their chemical structure.

Oxalic Acid—Oxalic acid is a good reducing agent and is sometimes used for bleaching wood. It has the appearance of lump sugar. It is a strong poison if ingested and can also cause severe burns to the eyes, skin, and nasal passages.

Chemical goggles must be worn by workers who handle oxalic acid. Impervious gloves will help to prevent skin contact. Workers should be instructed to wash their hands and faces after handling the acid.

Ozone—Ozone may be found either directly or indirectly. It is used to age wood rapidly, to bleach oils, and to dry varnish rapidly. It may be generated by such electrical equipment as copying machines and electronic air filters. It may be the result of electric arc welding, where enough energy is released into the atmosphere to change nitrogen and oxygen into both nitrogen dioxide and ozone. Without ventilation, the ozone concentration in the air gets up to about .06 ppm. for flux-covered electrodes, and up to about .5 ppm for barewire, argon-shielded welding of aluminum. (The TLV is .1 ppm.)

Like nitrogen dioxide, ozone is irritating to the eyes and mucous membranes. Breathing ozone in low concentrations (above .05 ppm) may cause dryness of the mouth, headaches, coughing, and pressure or pain in the chest, followed by difficulty in breathing. Ozone impairs the sense of smell, disguises other odors, alters tastes, and reduces the ability to think clearly. It also depresses the nervous system, slowing the heart and respiration and producing drowsiness and sleep. Excessive exposure may produce pulmonary edema.

General ventilation alone may be sufficient to prevent the accumulation of ozone in inhabited spaces. Enclosures can isolate ozone processes, and respirators may be needed in some situations.

Petroleum Naphtha—Petroleum (aliphatic) naphtha, sometimes called petroleum ether, also has a low toxicity, but is considerably more flammable than the Stoddard-type solvents, because its flash point is 0°F or below.

Plastics—By themselves, plastics generally pose no particularly problems with respect to toxicity or flammability. The various compounds in which they are found, however, such as in coating, adhesive, and molding formulations, contain other ingredients (solvents, accelerators, inhibitors, curing agents) which often introduce health and fire hazards. The presence of hazardous materials in plastic formu-

lations used in specific operations and procedures should be determined and appropriate preventive and precautionary measures taken to counteract the hazards involved.

Polyester Resins—When resins, accelerators, catalysts, and flammable solvents are used for cleaning, all precautions and safety measures pertaining to flammable materials (such as no smoking, welding, or burning in the immediate areas) should be enforced. Use of rubber gloves, goggles, and face shield during application of resin and glass cloth is recommended.

Phosgene—Phosgene is produced whenever a compound containing chlorine comes in contact with a flame or hot metal, as occurs in some types of welding, or with ultraviolet light. Low concentrations are mildly irritating to the eyes, nose, throat, and respiratory passages. Skin contact causes dermatitis. Symptoms of slight gassing may occur: dry burning throat, numbness, vomiting, chest pain, and cough with phlegm. There may be a shortness of breath.

Phosgene reacts with the moisture in the air passages to produce hydrogen chloride. As with the nitrogen oxides, the reaction to a moderately high exposure is delayed for several hours. When the gas dissolves in the fluid of the lung tissues, it causes severe burns. Large quantities of tissue fluid then flood the lungs, resulting in pulmonary edema.

For this reason, chlorinated solvents should be kept well away from welding operations or any operations in which ultraviolet radiation or intense heat is generated. Ventilation is also necessary.

Refrigerants—Problems which may occur during installation, modification, or repair of refrigeration units are leaks and, very infrequently, fire or explosion. Refrigerants may be considered in the following classes:

1. *Nonflammable substances where the toxicity is slight*, such as some fluorinated hydrocarbons (Freon). Although considered fairly safe, these refrigerants may decompose into highly toxic gases (such as hydrochloric acid, chlorine, and phosgene) upon exposure to hot surfaces (sweating, welding, and so forth) or open flames.
2. *Toxic and corrosive refrigerants* (such as methyl chloride and ammonia) may be flammable in concentrations exceeding 3.5 percent by volume. Ammonia is the most common

refrigerant in this category and is very irritating to the eyes, skin, and respiratory system. If there are large releases of ammonia, the area must be evacuated. Re-entry may be made by wearing appropriate respiratory protective devices and protective impervious clothing. As ammonia is readily soluble in water, it may be necessary to spray water in the room via a water mist-type nozzle to lower concentrations of ammonia.

If a refrigerant escapes, action should be taken for removal of the contaminant from the premises. If ventilation is used, exhaust from the floor area must be provided for heavier-than-air gases and from the ceiling for lighter-than-air gases.

Silicon Dioxide—Silicon dioxide (free silica) is found as a constituent in the coatings of several welding rods. It also occurs in a free, finely divided dust as the result of blasting and drilling. Depending on the extent of welding, significant concentrations of airborne free silica can be generated. Long-term exposure to excessive concentrations can lead to silicosis, a development of scar tissues in the lungs which prevents normal breathing. Like asbestosis, silicosis is incurable.

Stoddard Solvent—Stoddard Solvent has a low toxicity and may be used as general-purpose solvent or cleaner, or as a substitute for the more toxic chlorinated solvents. Although the flash point is above 100°F, Stoddard solvent is flammable, and appropriate precautions should be taken to minimize the fire hazard. Standard stock mineral spirits, paint thinner, and dry-cleaning solvents are similar to Stoddard solvent in fire and toxic properties.

Sulfuric Acid—Sulfuric acid is a strong dehydrating and oxidizing agent often found in pickling operations. It is rapidly destructive to tissues, producing severe burns. Concentrated solutions rapidly destroy any body tissue with which they may come in contact. Contact with the eye will result in almost immediate severe damage. Blindness may result if not promptly treated.

The inhalation of concentrated vapor or mist from hot acid will cause damage to the upper respiratory tract and possibly to the lung tissue. Continued inhalation of mist may cause a chronic inflammation of the upper respiratory tract and chronic bronchitis. Dermatitis may result from repeated contact with dilute solutions.

Sulfuric acid is not flammable. In high concentrations it may cause ignition of combustible materials by contact. The acid reacts with most metals to produce highly flammable hydrogen. The acid in its concentrated form reacts violently with organic materials and water, with evolution of heat. To determine if a hazardous mixture of hydrogen (produced by the action of the acid on metal) and air exists, commercial gas indicators are available. Containers of acid should be isolated from organic or combustible materials or oxidizers such as nitrates, carbides, chlorates, and metallic powders. Because hydrogen may be generated inside a drum or metal storage tank containing sulfuric acid, all means of ignition should be kept from these containers. Spills should be removed quickly by flushing the contaminated area with a large amount of water or by covering the area with dry sand, ashes, or gravel if no water is available. Any remaining traces of the acid should be neutralized with soda ash or lime.

Sulfuric acid is highly corrosive to most metals. NFPA 49, Hazardous Chemicals Data, provides safety information on this acid and others discussed in this appendix.

Toxic Metals and Their Compounds—Any operations involving toxic metals and their compounds which produce dusts, fumes, or mists are likely to create health hazards. Appropriate measures should be taken to avoid exposure to hazardous concentrations. Typical operations likely to contaminate the atmosphere are grinding, sanding, and buffing.

Toxic metals and their compounds most frequently found are discussed below.

Toluene and Xylene—Toluene vapor can cause narcosis. Exposure to low concentrations will cause fatigue, weakness, confusion, headache, dizziness, and nausea. Exposure to high levels may induce nervousness, and temporary liver and kidney damage. External effects include eye irritation, drying of the skin, and dermatitis. Respirators, other types of personal protective equipment, and careful cleansing on exposure will help to reduce the hazard. Toluene and xylene are classed as flammable liquids, and their vapors are considered toxic. Any operations involving these solvents should be surveyed for health and fire hazards. Many types of paints, enamels, lacquers, and adhesives are likely to contain one or both of these compounds as thinners.

Zinc and Zinc Oxide—Zinc is used in large quantities in the production of galvanized metal, brass, and various other alloys. Inhalation of zinc oxide fumes can occur when welding or cutting on zinc-coated metals. Exposure to these fumes can cause metal fume fever. Symptoms of metal fume fever are very similar to those of common influenza. They include fever (rarely exceeding 102°F), chills, nausea, dryness of the throat, cough, fatigue and general weakness, and aching of the head and body. The victim may sweat profusely for a few hours,

after which the body temperature begins to return to normal. The symptoms of metal fume fever rarely, if ever, last beyond a few hours. The subject can then return to work without any apparent after-effects but with an immunity to the fumes. However, this immunity is lost after a day or two away from the job. Therefore, workers are more susceptible to the onset of metal fume fever on Mondays or on weekdays following a holiday than they are on other days.

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Appendix B
NIOSH SUGGESTIONS FOR LABEL STATEMENTS

NIOSH SUGGESTIONS FOR LABEL STATEMENTS

PART I—NATURE OF HAZARDS AND HOW TO PROTECT AGAINST THEM

The number of statements used on a label will depend on the hazard the substance presents. Extremely dangerous materials will require extensive warnings and detailed instructions for safe use. The following statements are taken from *An Identification System for Occupationally Hazardous Materials* (U.S. Department of Health, Education, and Welfare, NIOSH, 1974).

A. Health Hazards

The major considerations in determining health hazards are:

- the modes of entry
- the speed of attack
- the effects, whether chronic or acute.

1. Nature of the hazard—The following are the statements recommended by NIOSH to identify on the label the health hazard of a given substance.

- Fatal if swallowed.
- Fatal if inhaled.
- Fatal if absorbed through the skin.
- Harmful if swallowed.
- Harmful if inhaled.
- Harmful if absorbed through the skin.
- Can cause allergic respiratory reaction.
- Can cause allergic skin reaction.
- Vapor (gas) may cause suffocation.
- Causes eye burns.
- Causes eye irritation.
- Causes burns.
- Causes irritation.
- Can be fatal or cause blindness if swallowed.
- Cannot be made nonpoisonous.
- Repeated absorption can cause bladder tumors.
- Rapidly absorbed through skin.
- Inhalation can be fatal or cause delayed lung damage.
- Harmful if inhaled and can cause delayed lung damage.
- Can cause delayed effect.
- Vapor extremely irritating.
- Extremely irritating gas and liquid under pressure.
- Gas extremely irritating.
- Lung injury and burns may be delayed.

- Contact with water or moist air liberates irritating gas.
- Contact with acid liberates poisonous gas.
- Contact with water or acid slowly liberates poisonous and flammable hydrogen sulfide gas.
- Liberates gas which may cause suffocation.
- Repeated inhalation or skin contact can, without symptoms, increase hazard.
- Causes severe burns which may not be immediately painful or visible.
- Can cause rash or external sores.
- Can cause burns or external sores.
- Liquid or vapor causes burns which may be delayed.
- May cause eye injury—effects may be delayed.
- Liquid penetrates shoes and leather causing delayed burns.
- May cause sterility.
- May affect unborn children.
- Cancer suspect agent.

2. Action necessary to protect against hazard—The following are the action statements recommended by NIOSH for use on labels of a substance which presents a health hazard.

- Do not breathe dust.
- Do not breathe vapor.
- Do not breathe mist.
- Do not breathe gas.
- Do not get in eyes, on skin or clothing.
- Prevent contact with food, chewing or smoking materials.
- Wash hands thoroughly after handling.
- Use only in well ventilated area.
- Keep container closed.
- Avoid prolonged or repeated contact with skin.
- Do not enter storage areas unless well ventilated.
- Avoid breathing dust of solution spray or vapor.
- Avoid prolonged or repeated breathing of vapor.
- Use special protective clothing and gloves.
- Wear goggles; neoprene, butyl or vinyl

gloves, neoprene shoes or boots; and clean protective outer clothing.

- Wear goggles; neoprene, butyl rubber or vinyl gloves.
- Always wear a self-contained breathing apparatus or full-face airline respirator when using this product.
- Have available emergency self-contained breathing apparatus or full-face airline respirator when using this product.
- Wear respirator approved by NIOSH or the U.S. Bureau of Mines for organic vapor, dust, etc.
- Wear goggles or face shield, rubber gloves and protective clothing when handling.
- Do not wear ordinary rubber protective clothing, including gloves and boots.
- Do not taste.
- This gas deadens the sense of smell. Do not depend on odor to detect presence of gas.
- Use fresh clothing daily. Take hot shower at end of work shift using plenty of soap.
- POISON (with skull and crossbones symbol).
- Avoid exposing women of child-bearing age.

B. Fire Hazards

The major considerations in determining fire hazards are:

- vapor pressure and density
- auto-ignition temperature
- explosive limits
- viscosity
- products of combustion
- extinguishing media

1. Nature of the hazard—The following are the statements recommended by NIOSH to identify on the label the fire hazard of a given substance.

- Strong oxidizer—contact with other materials may cause fire.
- Catches fire if exposed to air.
- Spillage may cause fire or liberate dangerous gas.
- Highly volatile.
- Contact with water or acid slowly liberates flammable gas.
- Contact with water may cause flash fire.
- May ignite if allowed to become damp.
- Heat, shock, or contact with other

materials may cause fire or explosive decomposition.

- Contact with other materials may cause fire or explosion, especially if heated.

2. Actions necessary to protect against hazard—The following are action statements recommended by NIOSH for use on the label of a substance which presents a fire hazard.

- Keep away from fire, sparks and open flame.
- Keep from contact with clothing or combustible materials to avoid fire.
- Drying of this product on clothing or combustible materials may cause fire.
- Spills on clothing or combustible materials may cause fire.
- Contents packed under water will ignite if water is removed.
- Avoid friction or rough handling because of fire hazard.
- Keep wet in storage—dry powder may ignite by friction, static electricity or heat.
- Wear goggles or face shield and fire-retardant clothing when handling.
- Clothing and vegetation contaminated with chlorate or its solutions are DANGEROUSLY FLAMMABLE. Remove clothing and wash thoroughly in water. Keep persons and animals off treated areas.
- Store in cool place.
- Keep container tightly closed.
- Loosen closure cautiously before opening.
- Store in cool dry place.
- Store in a cool place in original container and protect from direct sunlight.
- In case of fire, stop flow of gas. Use dry chemical or carbon dioxide when necessary to gain access to valve.
- Avoid spillage and contact with moisture or combustion.
- In case of spillage, flush with plenty of water and remove contaminated articles.
- Flush area with water spray.
- In case of fire, smother with dry sand, dry ground limestone or dry powder type materials specially designed for metal powder fires.
- Spillage may cause fire. Do not get on floor. Sweep up and remove immediately.

C. Reactivity Hazards

The major considerations in determining reactivity hazards are the substance's

- sensitivity to detonation: by shock or heat
- tendency to rapid polymerization
- reactivity with common substances
- ability to supply oxygen in a fire situation
- other special harmful properties

1. Nature of the hazard—The following are statements recommended by NIOSH to identify on the label the reactivity hazard of a given substance.

- Powerful oxidizer.
- Strong oxidizer.
- Strong acid.
- Strong caustic (alkali).
- Causes severe burns which may not be immediately painful or visible.
- Heat, shock, or contact with other materials may cause fire or explosion, especially if heated.
- Contact with other material may cause fire or explosion, especially if heated.
- Reacts violently with water, liberating and igniting hydrogen.
- May form explosive peroxides.
- Forms shock-sensitive mixtures with certain other materials.
- May explode if water content is 10% or below.
- Contamination may result in dangerous pressure.
- Liquid and gas under pressure.
- Extremely cold (F & C below zero).
- Highly explosive.
- Explosive.
- Inhibited monomer subject to violent polymerization.
- Liquid and gas under pressure.
- Gas under pressure.

2. Actions necessary to protect against hazard—The following are action statements recommended by NIOSH for use on the label of a substance which presents a reactivity hazard.

- Keep from contact with oxidizing materials, highly oxygenated or halogenated solvents, organic compounds containing reducible function groups or aqueous ammonia.
- Keep from contact with oxidizing materials.

—Keep from contamination by any source, including metals, dust and organic materials. Such contamination can cause rapid decomposition, generation of high pressures or formation of explosive mixtures.

—Solidifies at about ____ °F (____ °C) and may break container. Store in moderately warm place.

—Keep from any contact with water.

—Use only dry, clean utensils in handling.

—While making solutions, add slowly to surface to avoid violent splattering.

—Keep wet in storage—dry powder may ignite by friction, static electricity or heat.

—Do not add to hot materials; do not grind or subject to frictional heat or shock—explosive decomposition may result.

—Prevent contamination with readily oxidizable materials and polymerization accelerators.

—Do not allow to evaporate to near dryness. Addition of water or appropriate reducing materials will lessen peroxide formation.

—Do not add water to contents while in a container because of violent reaction and possible flash fire.

—Do not attempt to loosen or remove material from container with any tool.

—Wear goggles and DRY gloves when handling.

—Put nothing else in this container.

—Keep dry and handle only in suitable equipment to prevent metallic contamination. Consult manufacturer.

—Keep container tightly closed and away from water or acids.

—Keep container tightly closed; flush container clean before discarding.

—Do not put in stoppered or closed container.

—Note: Suck-back into cylinder may cause explosion. Under no circumstances should the cylinder entry tube be inserted in a liquid or gas without a vacuum break or other protective apparatus in the line to prevent suck-back.

—Store in original vented container.

—Store in cool place.

- Keep drum in upright position. Do not roll drum on side.
- Handle under inert gas atmosphere in DRY equipment.
- Keep from freezing.
- Loosen closure cautiously before opening.
- Store separately from, and avoid contact with, dehydrating materials and other materials.
- Keep away from fire.
- Open container carefully and only in dry oxygen-free or inert atmosphere.
- Store in cool dry place.
- Store in cool place in original container and protect from direct sunlight.
- Keep container closed to prevent drying out.
- Do not heat cylinders.
- Keep away from acids and heat.
- Never return unused HYDROGEN PEROXIDE to container. Dilute with plenty of water.
- Avoid spillage and contact with moisture or combustibles.
- Fire or high temperatures may cause explosive decomposition if confined.
- In case of fire, smother with dry sand, dry ground limestone or dry powder type materials specially designed for metal powder fires. Do not use carbon tetrachloride, carbon dioxide extinguishers or water.
- Do not use air pressure to transfer.

PART II—FIRST AID STATEMENTS

The following are ten first aid statements recommended by NIOSH for use on the label of a hazardous substance. Most manufacturers will provide on request appropriate first-aid directions.

CALL A PHYSICIAN AS SOON AS POSSIBLE—If swallowed, induce vomiting by sticking finger down throat or by giving soapy or strong salty water to drink. Repeat until vomit is clear. Never give anything by mouth to an unconscious person.

CALL A PHYSICIAN AS SOON AS POSSIBLE—In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. (Discard contaminated shoes).

CALL A PHYSICIAN AS SOON AS POSSIBLE—If inhaled, remove to fresh air. If

not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen.

CALL A PHYSICIAN AS SOON AS POSSIBLE—In case of eye contact, immediately flush eyes with plenty of water for at least 15 minutes. Remove contact lenses if worn.

CALL A PHYSICIAN AS SOON AS POSSIBLE—In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Flush skin with water. (Wash clothing before reuse.)

In case of contact, immediately wash skin with soap and plenty of water.

Do NOT induce vomiting. Call a physician as soon as possible.

Antidote: (Indicate commonly available antidote.)
Note to Physicians: (Give detailed specific treatment including drug dosage.)

Call the Life Squad or local emergency unit.

PART III—CLEANUP AND DISPOSAL INSTRUCTIONS

The following are cleanup and disposal instructions recommended by NIOSH for use on the label of a hazardous substance. For information regarding applicable local, state and federal regulations, contact the appropriate government bureau, including the Environmental Protection Agency.

- Flush spill area with water spray.
- Soak up spill with sand or earth. Do not use water.
- Flush away spill by flooding with water applied quickly to entire spill.
- Keep upwind of leak: Evacuate enclosed places until gas has dispersed.
- Dike spill and decontaminate by ...
- Do not flush into sewers.
- Dispose of sodium by burning carefully in an open fire.
- Sweep up spillage with strong calcium hypochlorite solution.
- Treat spillage with strong calcium hypochlorite solution and flush to sewer.
- In case of spillage, keep wet and remove carefully.
- Soak up with rags and dispose in covered metal containers.
- Consult local solid waste regulations for safe disposal.
- Do not sweep. Use vacuum cleaning equipment only.

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Appendix C
SAMPLE MATERIAL SAFETY DATA SHEET

The following Material Safety Data Sheet is recommended as part of *An Identification System for Occupationally Hazardous Materials* (U.S. Department of Health, Education, and Welfare, NIOSH, 1974).

MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION		
MANUFACTURER'S NAME	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO.	
ADDRESS		
TRADE NAME		
SYNONYMS		
II HAZARDOUS INGREDIENTS		
MATERIAL OR COMPONENT	%	HAZARD DATA
III PHYSICAL DATA		
BOILING POINT, 760 MM HG		MELTING POINT
SPECIFIC GRAVITY (H ₂ O = 1)		VAPOR PRESSURE
VAPOR DENSITY (AIR = 1)		SOLUBILITY IN H ₂ O, % BY WT.
% VOLATILES BY VOL.		EVAPORATION RATE (BUTYL ACETATE = 1)
APPEARANCE AND ODOR		

IV FIRE AND EXPLOSION DATA				
FLASH POINT (TEST METHOD)			AUTOIGNITION TEMPERATURE	
FLAMMABLE LIMITS IN AIR, % BY VOL.		LOWER	UPPER	
EXTINGUISHING MEDIA				
SPECIAL FIRE FIGHTING PROCEDURES				
UNUSUAL FIRE AND EXPLOSION HAZARD				
V HEALTH HAZARD INFORMATION				
HEALTH HAZARD DATA				
ROUTES OF EXPOSURE				
INHALATION				
SKIN CONTACT				
SKIN ABSORPTION				
EYE CONTACT				
INGESTION				
EFFECTS OF OVEREXPOSURE				
ACUTE OVEREXPOSURE				
CHRONIC OVEREXPOSURE				
EMERGENCY AND FIRST AID PROCEDURES				
EYES:				
SKIN:				
INHALATION:				
INGESTION:				
NOTES TO PHYSICIAN				

VI REACTIVITY DATA
CONDITIONS CONTRIBUTING TO INSTABILITY
INCOMPATIBILITY
HAZARDOUS DECOMPOSITION PRODUCTS
CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION
VII SPILL OR LEAK PROCEDURES
STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED
NEUTRALIZING CHEMICALS
WASTE DISPOSAL METHOD
VIII SPECIAL PROTECTION INFORMATION
VENTILATION REQUIREMENTS
SPECIFIC PERSONAL PROTECTIVE EQUIPMENT
RESPIRATORY (SPECIFY IN DETAIL)
EYE
GLOVES
OTHER CLOTHING AND EQUIPMENT

IX SPECIAL PRECAUTIONS

**PRECAUTIONARY
STATEMENTS**

**OTHER HANDLING AND
STORAGE REQUIREMENTS**

PREPARED BY: _____

ADDRESS: _____

DATE: _____

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Appendix D
OCCUPATIONAL HEALTH GUIDELINE FOR
DICHLORODIFLUOROMETHANE

U.S. Department of Labor,
National Institute for Occupational
Safety and Health

OCCUPATIONAL HEALTH GUIDELINE FOR DICHLORODIFLUOROMETHANE

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: CCL_2F_2
- Synonyms: Refrigerant 12; Freon 12; propellant 12; halon 122
- Appearance and odor: Colorless gas with a characteristic ether-like odor that is detectable only in concentrations well above the permissible exposure (above 20% by volume).

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for dichlorodifluoromethane is 1000 parts of dichlorodifluoromethane per million parts of air (ppm) averaged over an eight-hour work shift. This may also be expressed as 4950 milligrams of dichlorodifluoromethane per cubic meter of air (mg/m^3).

HEALTH HAZARD INFORMATION

Routes of Exposure

Dichlorodifluoromethane can affect the body if it is inhaled or if it comes in contact with the eyes or skin.

Effects of Overexposure

1. *Short-term Exposure:* Exposure to dichlorodifluoromethane may cause dizziness, involuntary trembling, unconsciousness, and death. It may also cause irregular heartbeat. If the liquid gets on the skin or in the eyes, it may cause frostbite.
2. *Long-term Exposure:* None known.
3. *Reporting Signs and Symptoms:* A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to dichlorodifluoromethane.

Recommended Medical Surveillance

The following medical procedures should be made available to each employee who is exposed to dichlorodifluoromethane at potentially hazardous levels:

1. *Initial Medical Screening:* Employees should be screened for history of certain medical conditions (listed below) which might place the employee at increased risk from dichlorodifluoromethane exposure.
 - Cardiovascular disease: In persons with impaired cardiovascular function, especially those with a history of cardiac arrhythmias, the inhalation of dichlorodifluoromethane might cause exacerbation of disorders of the conduction mechanism due to its sensitizing effects on the myocardium.
2. *Periodic Medical Examination:* Any employee developing the above-listed conditions should be referred for further medical examination.

Summary of Toxicology

Dichlorodifluoromethane vapor is a narcotic and can cause asphyxia at very high concentrations. At 800,000 ppm rats were deeply anesthetized, but 4 to 6 hours' exposure produced no permanent effects. At 200,000 ppm dogs and monkeys showed only tremors, salivation, and lacrimation. Inhalation by man at 150,000 ppm produces unconsciousness, while dizziness occurs at 50,000 ppm. Sniffing aerosols of fluorochlorinated hydrocarbons has caused sudden death by cardiac arrest, probably due to sensitization of the myocardium. In liquid form this substance may cause frostbite.

CHEMICAL AND PHYSICAL PROPERTIES

Physical Data

1. Molecular weight: 120.9
2. Boiling point (760 mm Hg): -29.8°C (-21.6°F)
3. Specific gravity (water = 1): 1.49 (at boiling point)
4. Vapor density (air = 1 at boiling point of dichlorodifluoromethane): 4.2
5. Melting point: -157.7°C (-252°F)

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

6. Vapor pressure at 20 C (68 F): 5.7 atm.
7. Solubility in water, g/100 g water at 20 C (68 F): 0.008
8. Evaporation rate (butyl acetate = 1): 380

Reactivity

1. Conditions contributing to instability: heat
2. Incompatibilities: Dichlorodifluoromethane reacts with chemically active metals such as sodium, potassium, calcium, powdered aluminum, zinc, and magnesium.
3. Hazardous decomposition products: Toxic gases and vapors (such as hydrogen chloride, phosgene, and hydrogen fluoride) may be released when dichlorodifluoromethane decomposes.
4. Special precautions: Liquid dichlorodifluoromethane will attack some forms of plastics, rubber, and coatings.

Flammability

1. Not combustible.

Warning Properties

Since dichlorodifluoromethane is practically odorless and is not an irritant, it is treated as a material with poor warning properties.

Grant states that "in ordinary occupational or domestic exposure to the gas, there is neither ocular nor respiratory irritation. Dogs, monkeys, and guinea pigs exposed to 20% of the gas in air for several hours a day for several days showed temporary intoxication with tremors, ataxia, and associated tendency to stare, salivate, and lacrimate, but no cumulative toxic effect and no specific ocular disturbance. The speed of reflex closure of the eyes is such that it seems extremely unlikely that any serious injury would result from an accidental spray of this substance in the eyes of human beings."

MONITORING AND MEASUREMENT PROCEDURES

General

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

Method

An analytical method for dichlorodifluoromethane is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 2, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00260-6).

- Gleason, M. N., Gosselin, R. E., Hodge, H. C., and Smith, R. P.: *Clinical Toxicology of Commercial Products* (3rd ed.), Williams and Wilkins, Baltimore, 1969.

RESPIRATORS

Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent the skin from becoming wet with liquid dichlorodifluoromethane or from becoming frozen from contact with vessels containing dichlorodifluoromethane.

Any clothing which becomes wet with liquid dichlorodifluoromethane should be removed immediately and not reworn until the dichlorodifluoromethane has evaporated from the clothing. Employees should be provided with and required to use splash-proof safety goggles where liquid dichlorodifluoromethane may contact the eyes.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to dichlorodifluoromethane may

occur and control methods which may be effective in each case:

Operation

Use in manufacture of aerosols for cosmetics, pharmaceuticals, insecticides, paints, adhesives, and cleaners; use in manufacture and extensive use as a refrigerant in home and commercial applications

Use as a blowing agent for cellular polymers; use as a solvent or diluent in fumigants for food sterilization; in paints and varnish removers, and in polymerization processes

Use as a foaming agent in fire extinguishing, aerosols, for surfactants; use in Immersion Quick Freezing of food products

Use in water purification; copper and aluminum purification, petroleum recovery, and in manufacture of glass bottles

Use in regulating devices for leak detection; in thermal expansion valves; use in manufacture of materials for electrical applications as insulators and generator windings

Controls

General dilution ventilation; personal protective equipment

General dilution ventilation; personal protective equipment

General dilution ventilation; personal protective equipment

General dilution ventilation; personal protective equipment

General dilution ventilation; personal protective equipment

Use in organic synthesis of Freons, and a polymerization catalysts; use as a working fluid for heat pumps and in hydraulic fluids

General dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

Eye Exposure

If liquid dichlorodifluoromethane gets in the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.

Skin Exposure

If liquid dichlorodifluoromethane gets on the skin, immediately flush the skin with water if the dichlorodifluoromethane has not already evaporated. If liquid dichlorodifluoromethane soaks through the clothing, remove the clothing immediately and flush the skin with water. Do not use hot water for flushing. If irritation is present after washing, get medical attention.

Breathing

If a person breathes in large amounts of dichlorodifluoromethane, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

Rescue

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND LEAK PROCEDURES

Persons not wearing protective equipment and clothing should be restricted from areas of leaks until cleanup has been completed.

If dichlorodifluoromethane is leaked, the following steps should be taken:

1. Ventilate area of spill or leak to disperse gas.
2. Stop flow of gas.

References

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RESPIRATORY PROTECTION FOR DICHLORODIFLUOROMETHANE

Condition	Minimum Respiratory Protection* Required Above 1000 ppm
Gas Concentration 10,000 ppm or less	Any supplied-air respirator. Any self-contained breathing apparatus.
50,000 ppm or less	Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece. A Type C supplied-air respirator with a half facepiece operated in pressure-demand or other positive pressure or continuous-flow mode.
Greater than 50,000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

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UNIT 10

WORKSPACE TESTING AND MONITORING

INTRODUCTION¹

To choose the proper sampling method before testing the atmosphere, a thorough knowledge of any hazardous substances likely to be present in the atmosphere is necessary.

An adequate number of tests should be taken to determine the level of atmospheric substances relative to their respective permissible exposure levels (PELs). Because some PELs are also ceiling levels, samples must be taken to determine peak emissions during various portions of the entire process, in addition to tests taken to determine the time-weighted average level.

Not only should the tests taken be sufficient in number to give an accurate profile of the atmosphere within the confined space, they should also be sufficient in length.

OSHA standards now stipulate that ceiling concentrations are to be measured over a fifteen-minute sampling period. Air samples collected within a shorter sampling period may miss peak concentrations occurring between tests.

Usually, changes in concentration will be less pronounced with gases and vapors than with particulate contaminants. However, marked variations in concentration are always possible. These may be intermittent or they may be relatively constant, depending upon the contaminant sources, their number, and the effectiveness of any ventilation control in use.

CHOOSING THE CORRECT SAMPLING METHOD

The best method of air sampling is dependent upon the particular substances and operations involved. Therefore, no one single procedure will be appropriate for every situation.

Chemical agents, for example, that do not represent too serious a hazard may be sampled for and measured relatively infrequently in accordance with routine safety practices.

Where there is a potential for serious danger, par-

ticularly where extremely hazardous materials are handled, continuous monitoring of the atmosphere is mandatory. Sampling points should be located at work stations, in areas frequented by workers, and in areas where leakage of contaminants to the atmosphere is most likely to occur.

A *spot* or *grab sample* may provide a fairly reliable measurement of a specific sample volume. However, this sort of sampling, if taken continuously on a single-sample collector, will yield only an average. It will not provide information as to fluctuations in concentration throughout the sampling period. Monitoring should preferably be conducted at the breathing zone of the worker.

Breathing Zone Samples

Sampling in the breathing zone may require a series of samples (that is, sampling for a given length of time every hour), or it may involve only one or two relatively long-term samples covering the work day.

Area Samples

Area samples can be used to determine whether the area should be isolated and restricted to prevent employees from entering a highly contaminated area.

FACTORS TO CONSIDER WHEN SAMPLING

Sampling of confined spaces, as with any testing, is only effective if it conforms to certain criteria.

The test must be *valid*. Only calibrated instruments whose accuracy can be certified should be used.

The test must be *properly interpreted*. The worker behind the instrument is at least as important as the instrument itself.

The test must be *followed by appropriate action*. If any identified hazards are left uncorrected, the test will be rendered worthless.

Ideally, testing should indicate that the level of contaminant does not exceed that allowed for in

preliminary plans. If the contaminant does exceed its allowable level, further precautions will need to be carried out and a new test conducted.

However, the mere fact that a contaminant is concentrated within certain limits is not sufficient grounds for determining that it is safe. If preliminary plans make no allowance for the presence of any contaminant at all, even at a very low level, then a problem is obviously indicated and further investigation is required. It may well be that the contaminant present is only an insignificant residue which will disappear. On the other hand, the fact that the contaminant is there at all may mean that a line was not blanked, a path for contaminant travel was not discovered, or a pocket of materials was not foreseen.

Location

Location is important in sampling because the hazard may be restricted only to a small portion of the entire space. Primarily it is important to remember the rule, *test the whole space*.

Errors may result if selection of the location is imprecise. Materials such as liquids with low flash points in locations where air currents are weak may register as hazardous only when the probe of the test instrument is in actual contact with the surface, which is not an advisable means of testing, since liquid could easily be drawn into the instrument. Even in stronger air currents, the readings may have to be taken close to the surface. Although there may be readings elsewhere, these will be much lower than the actual hazard of the material.

Air currents may pose another problem, too. Fresh air entering the atmosphere may dilute the contaminant. A test taken at a point where the contaminant is detected will indicate a concentration that may be considerably lower than at other points within the confined space. Therefore, tests at several points are recommended in confined spaces where air currents are present.

Time Factor

The length of time for which an individual sample is taken is a factor whenever there are fluctuations in the concentration of the contaminant.

If the level of the contaminant does fluctuate, it must be determined whether the hazard depends on the average of concentration of contaminant, or whether it is essential that it never exceed a certain level.

Where the average is important, the test instrument should take the sample over a period of time.

The result will then be the average. Where readings fluctuate, as in a combustible gas indicator, some knowledge of averaging techniques is required.

Instruments

Instruments used for sampling, like the sampling procedure itself, must also meet certain criteria in order to be regarded as accurate.

They should be capable of detecting the contaminant without interference from other materials that may be present.

They should be accurate to the lowest level of concentration at which the contaminant becomes hazardous.

They should be calibrated before use and checked for accuracy and operability.

The effect of any change in temperature upon the applicability of the instrument must be known. Oxygen deficiency may affect instruments as well. A level of less than 10% may cause hotwire combustible gas instruments to give false readings.

Specific instruments and detailed calibration requirements will be discussed more fully later in this unit.

TESTING PROCEDURES FOR CONFINED SPACES

The testing and examination of a confined space will involve certain steps as a matter of established routine.

Initial testing is to be performed from outside the space. Testing into the interior of the space may be performed by drop tests or by insertion of sample probes and hoses into the space.

When initial tests indicate the presence of hazardous concentrations of flammable or toxic substances or oxygen deficiencies, workers should not be allowed to enter the space. The space should be ventilated and/or cleaned to remove flammable and toxic gases or vapors and to provide proper oxygen levels. Where toxic or flammable substances or oxygen deficiencies are detected, the source or cause should be determined and eliminated wherever possible.

When initial tests do not indicate the presence of hazardous concentrations of flammable or toxic substances or oxygen deficiencies, the space may be entered and tests performed progressively throughout the space. If these tests indicate the presence of hazardous atmospheres, the tester must exit and the space be ventilated.

If tests throughout the space indicate that the

atmosphere is safe, the space should be inspected for the presence of flammable, combustible, or toxic residues; blisters or scale which may trap hazardous substances; and rags, rope, wood, and other materials which may become dangerous upon application of heat. Additionally, any specific structure, equipment, or location which may be affected by the intended work should be tested and/or inspected as applicable.

Where appropriate cleaning and/or ventilation fails to remove hazardous gases or vapors from a space, and it is necessary for workers to enter the space to conduct further confined workspace testing, inspections, evaluations, or similar operations, such entries are subject to several restrictions.

All entries into spaces which contain hazardous concentrations of toxic or flammable gases or vapors must be specifically authorized by the appropriate authority.

Workers entering spaces must be equipped with NIOSH-approved respiratory protection, safety clothing and equipment such as harness and life line, and approved explosion-proof or spark-proof equipment as necessary. A trained observer should be stationed outside the space to lend assistance in the event of an emergency.

Workers are not to enter spaces which contain flammable atmospheres above 10% of the LEL or toxic atmospheres which are IDLH (immediately dangerous to life and health) under any circumstances. (It is important to note here that atmospheres containing 5%-15% methane in a concentration of 12% or more oxygen is highly explosive.)

Workers should never enter a space which contains an oxygen-enriched atmosphere.

Periodic and Continuous Monitoring

Many operations, due to their potential for generating hazardous conditions, require periodic or continuous monitoring as the work progresses to ensure that safe conditions are maintained. The frequency of testing and the types of tests to be conducted depend on prevailing conditions in the confined space and on the nature of the operations. The following types of operations must be carefully evaluated for periodic or continuous monitoring:

1. Hot work which has the potential to generate flying sparks or hazardous concentrations of toxic gases and vapors;
2. Application of preservatives, paints, epoxies, adhesives, etc., which may involve hazardous concentrations of toxic or flammable vapors;

3. Cleaning operations, sludge removal, etc., which may produce or cause release of hazardous concentrations of toxic or flammable vapors;
4. Any similar operations with the potential for producing or releasing toxic, flammable, or asphyxiating substances into the atmosphere of the confined space.

TESTING FOR SPECIFIC HAZARDS²

The instrument selected for any use should be simple to use, requiring minimum set-up in the field. Corrosive or hazardous sampling collection media should be avoided, and, obviously, the device chosen should be compatible with the conditions under which it is to be used.

There are numerous instruments and procedures used for testing hazardous atmospheres. Currently, the general preference is for a large number of highly-specialized instruments, rather than for streamlined, "catch-all" instruments.

Direct-Reading Instruments

Direct-reading instruments are devices in which the sampling and analysis are carried out within the instruments, and from which the required information can be read (from a dial or indicator) directly. Direct-reading instruments may be either of the portable or of the fixed-site variety.

Direct-reading samplers include simple devices such as colorimetric indicating tubes in which a color change indicates the presence of the contaminant in air passed through the tube, or instruments which are more or less specific for a particular substance. In the latter category are carbon monoxide indicators, combustible gas indicators and mercury vapor meters.

Some instruments are designed to accomplish another very important task, that of screening, as a means of determining whether further and more extensive sampling will be required.

Direct-reading instruments are used for preliminary evaluations to locate the source of hazardous agents and to ascertain whether OSHA air standards may have been violated.

SAMPLING TECHNIQUES USING DIRECT-READING INSTRUMENTS³

Direct-reading instruments offer the user many distinct advantages. Not only can they provide an immediate readout of atmospheric hazard levels, they can also continuously record these levels, provide alarms, and activate controls to correct the sit-

uation (open doors, turn on ventilation, shut down a process, etc.).

Direct-reading instruments can be classified into four main types.

1. Analyzers provide a visual readout only.
2. Monitors produce audible and/or visual alarms that warn workers of an atmospheric hazard.
3. Recorders provide a permanent record of hazard levels. Recorder outputs are often an option with analyzers or monitors.
4. Dosimeters read the total concentration of contaminant, compared to the time-weighted average (TWA), which should be known when chronically toxic substances are measured.

In all four types of instruments, there are two methods of exposing the sensing device to the atmosphere—sample draw and diffusion. In sample-draw instruments, the atmosphere is pulled into the device by using either a hand aspirator or a pump. In diffusion instruments, the sample reaches the sensor by air movement.

Sample drawing has long been the accepted technique. Diffusion instruments, however, are gaining acceptance.

There are distinct advantages to the use of diffusion instruments. No pumps or moving parts are required. The sensor can be placed in the monitored environment. And, in remote locations, it is normally easier to run wires than a sampling line.

But, there are disadvantages as well. Some sensing techniques require a continuous sample flow (the electrochemical toxic gas sensor is an example). For atmospheres at very high or low temperatures, with excessive moisture or particulate matter, or with high air turbulence, a diffusion sensing will not provide as accurate a reading as will sample drawing. In limited-access areas, diffusion sensing cannot always be used.

The primary advantage of sample drawing is that the sensor is housed inside the instrument, providing a sheltered environment.

There are several disadvantages. Any leak in the sampling system will cause the reading to be lower than the actual atmospheric conditions, except when sampling from a pressurized line or tank. The transport time through the sampling line can become significant when the distance between the atmosphere and the sensor is increased. Pumps are often unreliable, but unless a flow alarm is incorporated in the system, the user may not be aware when his instrument is malfunctioning. Long sample lines are very cumbersome and inconvenient. If the sample draw system is used in a cold environ-

ment, a sample from a warmer area could condense or even freeze in the line. If a combustible vapor is being measured, a decrease in temperature may cause the vapor to condense below its flash point, giving a safe reading that is inaccurate. Many flammable or toxic substances can be absorbed by the sampling line, giving a lower reading than is accurate.

There are some instruments that use the best features of both sample draw and diffusion techniques. With a sample draw kit, the atmosphere in the confined space can be tested before an entry is made. When the sample has been drawn, the kit is removed. The atmosphere contacts the sensors by natural air movement. No further involvement of the worker is required.

OXYGEN DEFICIENCY⁴

Oxygen deficiency can occur in any confined space. It can kill quickly and without warning. The level of oxygen in a confined space can become dangerously low in a short time.

Normal fresh air is 20.8 percent oxygen. Most safety standards require a minimum oxygen level of 19.5 percent. At this level, there probably will be no discernible physical symptoms. Below this level, symptoms will appear, but they are often so slight or perhaps even so pleasant that they go unnoticed. At 16 percent, for example, a slight difficulty in breathing and a ringing in the ears may develop. Drowsiness may also appear at this level, and the worker may become unable to think clearly. Remaining in such an environment will eventually induce a state of euphoria. As the level of oxygen falls to 12 percent, loss of consciousness, and possibly of life, will result.

Scaling and sand-blasting operations in a metal tank can expose rust and alter an environment that has tested safe. As well, oxygen deficiency can continue long after a fire has been extinguished.

MEASURING OXYGEN LEVELS⁴

Various types of portable instruments to measure oxygen levels in confined spaces are available. Some offer semicontinuous monitoring; others detect and monitor combustible gases and vapors as well as oxygen deficiency.

Most direct-reading, oxygen-sampling instruments are small and lightweight, and require little maintenance. They usually operate an alarm when the oxygen level falls below 19.5 percent. Many include a remote sensor for probing manholes and tanks.

Measuring the amount of oxygen in the air of the confined space is generally done by means of an instrument containing an electrochemical sensor. The sensor consists of a sensing electrode, a counter electrode, a housing containing a basic electrolyte, and a Teflon membrane. The oxygen molecules diffuse through the membrane into the sensor. Electrochemical reactions at the two electrodes produce an electron flow. This minute current, which is directly proportional to the oxygen level seen by the sensor, passes through a temperature-compensating electronic circuit. The resulting voltage activates a meter display which is usually calibrated in percentage of oxygen.

Meters

Instruments of the meter type are available for measuring oxygen deficiency.

Solution Devices

There are several devices on the market which use solutions to absorb oxygen. These are convenient, but they have the disadvantage of requiring refilling with fresh solutions. It is important that solutions be checked frequently to assure that they are still active.

Portable Oxygen Indicators

A portable oxygen indicator is a compact instrument giving approximately the same performance as the non-portable model, in that it gives a direct reading of the percentage of oxygen in the atmosphere.

COMBUSTIBILITY

After the confined workspace has been tested for oxygen deficiency, it should be tested for concentrations of combustible materials.

Instruments to detect combustible substances measure the level of the substance and record it as a percentage of the amount in the air necessary for an explosion to occur. There are three ranges, based on the level of gas in relation to the amount of oxygen in the air: lean—too little gas in the air to support combustion; explosive—enough gas in the air to support combustion; and rich—too much gas in the air to support combustion.

These ranges are defined further by lower and upper explosion limits (LEL and UEL). LEL defines the low point at which a given gas will explode in air; UEL defines the high point. The terms lower and upper flammable limits (LFL and

UFL) are used interchangeably with LEL and UEL.

Combustible gases create special hazards. Vapors such as butane and propane are heavier than air and form pockets of combustibility in depressions or other low areas of tanks and spaces. If access to a confined space is from the top, a cursory check near the opening may fail to detect pockets of a heavier-than-air combustible gas or vapor deeper within the confined space.

On the other hand, lighter-than-air combustible gases, particularly methane, accumulate in high spots. So pockets of methane, a byproduct of anaerobic bacterial activity, may be an immediate hazard at the point of entry into the confined space.

Finally, it's important to know that layering of gases may occur in the confined workspace. Testing should be performed in steps from the top to the bottom of the space.

There are several techniques for measuring concentrations of combustible gases in the air.⁶

In thermal conductivity devices, air is pumped across a heated element. If a gas other than air is present, it may absorb heat from the element at a rate different from that for pure air. The electronics of this type of instrument sense the change of temperature and provide a meter indication.

Semiconductor sensors use an electrical resistance change of the semiconductor material when the gas being tested is absorbed on that surface.

Photometric devices measure the amount of light energy absorbed in a gas sample.

Optical refractive index devices operate on the principle that different gases refract light at different angles.

Catalytic devices are the most widely used for determining the presence of combustible gases and vapors. When certain metals such as paladium and platinum are heated and exposed to combustible gas/air mixtures in concentrations below the flammable region, the mixture will burn near the surface of the metals. Paladium and platinum act as a catalyst, enabling this combustion to occur even at very low gas concentrations.

In some instruments, the catalyst metal takes the form of a wound filament connected to a Wheatstone bridge circuit.

The Wheatstone bridge circuit uses the principle that a wire's electrical resistance is increased with increasing temperature. The filament is heated by a controlled electrical current. In the presence of a flammable gas, the catalytic filament burns the gas, and increases in temperature and in electrical

resistance. This causes an electrical signal to be displayed on the meter. If the meter is calibrated from 0 to 100% LEL, the meter output will accurately indicate the gas level as the gas level increases.

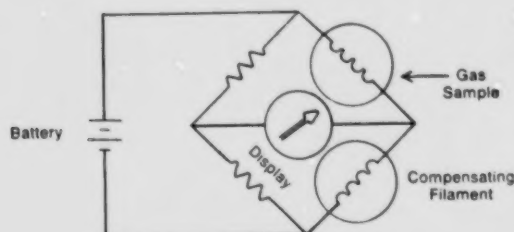


Figure 10.1. Wheatstone Bridge Circuit. Courtesy of Rexnord Safety Products.

A recent improvement on this technique involves a sensing element redesign. The filament has a ceramic bead upon which a catalyst (palladium or platinum) is deposited. This modification allows operation at a lower temperature, increasing sensor stability and life. The temperature-compensating bead is physically identical to the sensing bead, but it is not catalytically treated, nor is it sensitive to combustible gas.

The flame arrestor in the sensor unit prevents propagation of a flame outside the filament chamber should the instrument be used in an environment containing more than 100% LEL gas.

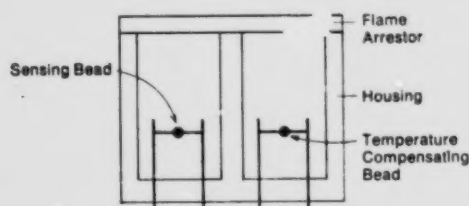


Figure 10.2 Combustible Gas Sensor. Courtesy of Rexnord Safety Products.

This technique is sensitive to all combustible gases and vapors. To determine the explosive concentration of a variety of different gases and vapors, calibration curves are available correlating meter readings to individual gases.

The majority of combustible gas indicators operate on the hot wire or Wheatstone bridge theory.

The most common type of hot wire instrument has a single measurement range, usually from 0 to 100% LEL. Generally, this device is manufacturer-calibrated for one of the hydrocarbon vapors. Therefore, the instrument will respond to other, similar hazards as it typically would to the substance for which it was designed. These vapors are representative of a large class of hazards.

Dual-range hot wire instruments give full scale readings of combustibles in two ranges: 0 to 100% LEL, and 0 to 10% LEL. The second range can gauge much smaller concentrations and can more accurately detect very small leaks.

Hot wire instruments can measure combustibles only up to their LEL. They work best when used where the oxygen content is 20.8 percent. When the combustible gas concentration is above the LEL, or when the test atmosphere contains less than ten percent oxygen, other devices should be used.

A relatively new device for detecting combustible gas or vapor uses a semiconductor to sense the contaminant. However, a semiconductor may be misleading, as it can sense anything in the atmosphere other than fresh air. It can therefore respond as easily to moisture and toxic substances as to combustible substances.

Most small portable instruments operate on carbon batteries. Some use nickel-cadmium batteries to provide semicontinuous monitoring for up to ten hours.

TOXICITY

The test for toxic substances in the confined space atmosphere is to be performed last, after the tests for oxygen deficiency and combustibility have been completed. Many of the more common substances encountered in the work environment are both toxic and flammable, but as a rule, the toxic effects of substances can occur at a much lower concentration than the flammable effects. The most valuable monitoring instruments are those capable of measuring low-level concentrations.

It is important to keep in mind, however, that few instruments are capable of singling out one specific substance without detecting any others. While such complex instruments are theoretically possible, the cost of developing them would probably outweigh the benefits of having them.

ORGANIC VAPORS

There are many sources of organic vapors in the work environment. Chemical solvents are one

major source. Some of these solvents are direct products of chemical processes, while others are byproducts. Some solvents, such as benzene or toluene, are pure hydrocarbons; others, such as chloroform, are hydrocarbons that contain chlorine.

Hydrocarbons are compounds that contain only carbon and hydrogen. Examples are methane and butane. They can be alkanes, unsaturated hydrocarbons (alkenes and alkynes), or aromatic hydrocarbons (such as benzenes and naphthenes). Hydrocarbons are present in the air as a result of many industrial processes and petrochemical operations.

The American Conference of Governmental Industrial Hygienists (ACGIH) lists more than 373 toxic substances. ACGIH publishes generally-accepted exposure limits, or threshold limit values (TLVs), for all of these substances.

The maximum level of a toxic substance to which an individual can be safely exposed for eight hours a day, forty hours a week, is called the time-weighted average (TWA). A short-term exposure limit (STEL)—the amount to which a worker can be exposed for up to fifteen minutes—is also set for each substance, as is a TLV ceiling, an amount that cannot be sustained for even a moment. All values are expressed in parts per million or in milligrams per cubic meter.

Toxic substances found in confined spaces fall into two categories: irritants and chemical asphyxiants. Irritants irritate respiratory and nervous systems at low concentrations and can cause death at higher levels. Chemical asphyxiants prevent the body from using its oxygen supply. However, these contaminants cause physiological damage long before they reach levels high enough to cause oxygen deficiency.

INSTRUMENT CLASSIFICATIONS

The three basic classifications of instruments for monitoring organic gases and vapors are combustible gas indicators, hydrocarbon analyzers, and general organic vapor analyzers.

Combustible gas indicators are used to detect combustible or flammable gases or vapors in air. The normal measuring range is from zero gas to the lower explosive limit (LEL). There are general-purpose instruments that are calibrated on typical hydrocarbons such as pentane, heptane or hexane. Others may be calibrated on a specific gas, such as methane. Combustible gas indicators are not normally suitable for measuring gas or vapors for toxicity (threshold limit values in low parts permission).

Hydrocarbon analyzers are instruments responding to all hydrocarbons. They use either flame ionization detectors or electrochemical sensing devices. They are not designed for specific contaminants, but they are useful in a monitoring system.

Ionization devices generate ions (electrically charged atoms or molecules) by techniques that include burning the gas sample in a hydrogen flow, exposure to light of certain frequencies, or exposures to radioactive material.

Electrochemical devices give an electrical signal when the gas sample comes in contact with the chemical sensor.

The principle of operation of one widely-used electrochemical toxic gas detector is the oxidation of toxic gas at a potential-controlled electrode. The basic components of the instrument are an electrochemical sensor, a sampling pump, and an electronic control and measuring circuit. The sensor consists of a sensing electrode, a counter electrode, a housing containing an acid electrolyte, and a Teflon membrane which is porous to gas but nonporous to liquid. The membrane allows the gas to diffuse into the reaction site while containing the acid solution.

Gas molecules come in contact with the acid solution at the sensing electrode. The electrochemical oxidation of the toxic gas at the reaction site generates a current. The current flows between the sensing and counter electrodes. The current is directly proportional to the concentration of the gas and is displayed on the meter in parts per million.

Organic vapor analyzers are in a broader category than the instruments previously mentioned. Most of them can detect all organic vapors.

Colorimetric Detection

There is a unique approach for instrumentation based on the color-inducing property of chemicals when they react with other chemicals. Detector tubes are the current method of colorimetric detection. The tubes consist of a solid reagent chemical and a piston-type sampler pump or bellows pump that draws the sample through the detector. Tubes for individual contaminants and for combinations of similar compounds are available.

These devices can sample the atmosphere in a confined space very quickly. However, their limitations can be serious. First, they are not precise. They give only a general indication of the level of a particular contaminant. Then, too, some toxic compounds do not produce a chemical reaction that permits the use of direct-reading tubes. A special

reactor tube that liberates a measurable element from the sample substance must be used in these cases.

In addition, most detector-tube systems cannot differentiate one substance from another. Personal sampling pumps with adsorbent tubes containing either charcoal or silica gel should be used for this purpose.

The concept behind detector tubes can be taken a step further by the addition of optical sensors to detect the color change or length of stain. Recorders/integrators may be used to obtain a direct reading in terms of a time-weighted average.

Colorimetric monitoring systems consist of the following:

1. A personal sampling device,
2. A sample collection media,
3. An optical sensing element, and
4. A recorder/integrator.

It is theoretically possible to have a base instrument with interchangeable sample collection media and some accessories to cover a broad variety of contaminants.

DEFINITIONS

Calibration is the determination of the true value of a measurement. It includes three variables: the instrument reading or indication, the quantity of contaminant in the air, and the quantity of air sampled.

Precision is a measure of the reproducibility of the results of a test on a homogeneous sample under controlled conditions, regardless of whether or not the observed values are the true values.

All measurements and calculations are subject to two broad classes of errors: determinate and indeterminate errors. Any error that is discovered and allowed for in the form of a correction leaving a margin for its effect is a *determinate error*. Errors that either cannot be or are not properly allowed for are known as *indeterminate errors*. Such deviation is due to the combined effect of a large number of undetermined causes, and it is known as *accidental errors*.

The word *precision*, then, is used to denote reliability; that is, the extent to which a result is free from accidental errors.

Accuracy is a comparison of the amount of substance determined by the test method and the amount actually present.

The accuracy of a measuring instrument will depend upon the stability and reproducibility of the device and upon the care with which it was calibrated. The accuracy of the instrument does not

exceed the initial calibration.

All air-sampling instruments should be calibrated when they are received from the manufacturer and before they are used in the field.

CALIBRATING THE INSTRUMENT

The only way to be sure that an instrument is performing properly is to check the calibration. Any instrument used to test confined spaces should be calibrated regularly, and the calibration recorded and verified at the start and finish of each job. Additional checks should be made if there is any possibility that the equipment has been contaminated.

The calibration may be checked by introducing directly into the instrument a known concentration of gas in air. The response may be then compared to the standard response data supplied by the manufacturer.

EQUIPMENT SAFETY

Where combustible gases or vapors are routinely present or where they may be present accidentally, special safety precautions must be taken. In the first situation, all equipment must be either intrinsically safe (low-energy devices which do not release sufficient energy to cause an explosion even in the event of an instrument malfunction) or mounted inside an approved heavy-duty, explosion-proof enclosure. In the second situation, equipment must be non-incendive (that is, it must be incapable of releasing sufficient energy for ignition during normal operation).

As an example, a portable combustible gas detector with rechargeable batteries which may be intrinsically safe should not be operated with the battery charger connected in an environment where combustible gases or vapors are routinely present. The battery charger might provide sufficient energy for ignition of a flammable mixture in the event of a malfunction.

Sensor and instrument location is extremely important. To locate the sensor for continuous monitoring, it is often wise to perform a spot-check survey with a portable analyzer. Sensor or sampling line location can be determined from the results of the survey and from several other considerations. Sensor placement should be low for gases heavier than air and high for gases lighter than air. Air currents within the confined space should also be taken into consideration. Sensors should be located near potential hazards such as pumps, pressure relief valves, and solvent storage containers and stacks. If sample lines are used, line length, possible condensation of particulate contamination, and instru-

ment response to flow and pressure variations must be considered.

INSTRUMENT SELECTION

Primary considerations in choosing any atmospheric monitoring device are the instrument's intrinsic safety and reliable performance in the environment to be tested.

Other prime factors in choosing an instrument are:

- Sensor function (accuracy, reliability, specificity);
- Alarm capability;
- Cost;
- Construction and design (portability, ruggedness, minimal margin for human error);
- Appropriate sampling capability (sample draw, diffusion, or combination of both);
- Ease of operation;
- Ease of calibration;
- Sensor life;
- Availability of manufacturer's service.

Secondary considerations are:

- Recording capability;
- Rechargeable batteries;
- Flow and battery alarms;
- Continuous or intermittent sampling;
- System check button.



This worker is testing a manhole with a hydrogen sulfide detector. Reprinted with permission from "Working Safely in Confined Spaces," *Plant Engineering*, January 21, 1982, p. 139.

EXPOSURE PROTECTION FOR THE TESTER

Where the degree of the hazard within the confined space is unknown, and where there is no precedent, the tester should be equipped with appropriate respiratory equipment. It is especially necessary that this be actually worn where there are hazards such as oxygen deficiency, hydrogen sulfide, and cyanide, whose effects may manifest themselves quickly and without warning.

Chemical cartridge respirators, supplied-air respirators, and self-contained breathing apparatus are the three main types of respiratory equipment required where the hazard is not known.

In addition, protective equipment such as gloves and coveralls may be recommended in atmospheres that may contain irritating contaminants.

CONCLUSION

This unit provides basic information regarding test instruments for each of the three types of hazardous atmospheres in confined spaces. The next unit, "Procedures Workshop: Atmospheric Test Procedures and Instruments," is designed for use in hands-on classroom situations.

Notes

1. This section is adapted from *Fundamentals of Industrial Hygiene* (Chicago: National Safety Council, copyright 1971) Chapter 18, "Air Sampling Instruments" by Julian B. Olishifski.
2. *Ibid.*
3. Adapted from *Atmospheric Monitoring for Employee Safety*, a pamphlet prepared by Rexnord Safety Products, Malvern, PA, p. 10 (adapted slightly).
4. Adapted from Julian B. Olishifski, *op. cit.*
5. Adapted from *Plant Engineering*, January 21, 1982, "Working Safely in Confined Spaces," by George L. Morse and Richard L. Swift of Mine Safety Appliances Company, Pittsburgh, PA.
6. Adapted from Rexnord, *op. cit.*

References

1. Naval Ships' Technical Manual (NAVSEA S9086-CH-STM-030/CH-074 V3 "Gas Free Engineering").
2. NAVSEA S6470-AA-SAF-010, "Gas Free Engineering Program."
3. Regulation 196-64, "Notes of Regulations for Vessel Entry," Technical Service Memorandum No. 17, Industrial Safety Act, Ontario.

Instruction Key—Unit 10

Workspace Testing and Monitoring

Terms

1. Time-weighted average (TWA): the maximum level of a toxic substance to which an individual can be safely exposed for eight hours a day, forty hours a week
2. Short-term exposure limit (STEL): the amount to which a worker can be exposed for fifteen minutes
3. TLV ceiling: a threshold limit value that cannot be safely sustained even for a moment (NOTE: all of the above values are expressed in parts per million or in milligrams per cubic meter)
4. Calibration: the determination of the true value of a measurement, including instrument reading, contaminant quantity, and air quantity
5. Precision: a measure of the reproducibility of the results of a test on a homogeneous sample under controlled conditions
6. Accuracy: a comparison of the amount of substance determined by the test method and the amount actually present

Points for Discussion

1. Choosing the correct sampling method
 - a. spot or grab sample
 - b. breathing zone sample
 - c. area sample
2. Factors to consider when sampling
 - a. criteria: validity, proper interpretation, follow-up of proper action
 - b. goal
 - c. location
 - d. time factor
 - e. instruments
3. Testing procedures for confined spaces
 - a. initial testing from outside the space
 - b. progressive testing from inside the space
 - c. inspection for hazardous residues
 - d. entry for further investigation when standard procedures have proven insufficient
 - e. periodic and continuous testing
 - f. maintaining certificates
 - g. re-testing spaces
4. Testing for specific hazards
 - a. direct-reading instruments
 - b. colorimetric methods
 - c. oxygen deficiency
 - d. combustibility
 - e. toxicity

Questions

More than one answer may be correct for each of the following questions.

1. An oxygen-deficient atmosphere is an atmosphere that has less than _____. This is also the level at which portable and permanent monitors will begin to sound an alarm.
 - a. 10% oxygen
 - b. 21% oxygen
 - c. 15% oxygen
 - d. 19.5% oxygen
2. If a confined space is found to be oxygen deficient, the most important and *first* step that should be taken is to:
 - a. Call the company safety department
 - b. Call the immediate supervisor
 - c. Ventilate the confined space
 - d. Insure that no one is in or enters the confined space.
3. When working in a confined space, which of the following are *always* recommended?
 - a. Portable or permanent oxygen monitor
 - b. Communication with personnel outside
 - c. A fire extinguisher
 - d. An hourly oxygen level check.
4. If a test is conducted in a confined space and the oxygen meter begins to sound an alarm, the oxygen level in the confined space is probably:
 - a. 19.5%-21.0%
 - b. 0.0%-19.5%
 - c. 19.5%
 - d. 10.0%-21%

Answers

1. (d) 19.5 percent oxygen
2. (d) Insure that no one is in or enters the confined space.
3. All four of these are required.
4. (b) 0.0% to 19.5%

Adapted from a questionnaire prepared by the Bechtel Power Corporation.

UNIT 11

ATMOSPHERIC TEST PROCEDURES AND INSTRUMENTS

While all of the manufacturers' instruments discussed in this unit are similar in operation, their unique features make it imperative for the user to become fully familiar with the fine points of each specific instrument. In this manner, errors will be avoided and more reliable results produced. Although only two manufacturers' instruments are used for demonstration purposes in this workshop, it is important that we stress that other manufacturers produce test instruments of equal acceptability.

For each instrument we discuss in this unit, we will examine its purpose and characteristics, theory of operation, precautions and limitations, nomenclature, operating procedures, calibration, and maintenance.

INTRODUCTION: EVALUATING THE ENVIRONMENT

The sampling techniques and instruments discussed in previous units operate on the principles of diffusion and sample drawing. The simplest method is diffusion where the instrument or a remote sensor is placed directly in the environment.

GENERAL TESTING PROCEDURES¹

To review briefly the testing procedures discussed in Unit 10, we will examine the necessary steps.

The first test should be taken from outside the structure by inserting a probe into the confined atmosphere through a vent hole or some other opening. The purpose of this initial test is to determine whether the atmosphere is oxygen deficient and whether any lighter-than-air combustibles have accumulated near the entrance to the structure.

Once this test is completed, tests may then be conducted for oxygen content and for combustible gases or vapors in the atmosphere. These further tests should still be conducted from the outside,

using sampling lines or a probe. Testing should always start at the bottom of the structure and continue adjacent to any pipes, conduits, or cables in the structure. The areas around an irregular surface of the interior should be tested. If the atmosphere tests free of combustibles and has an adequate oxygen level, the next series of tests should be conducted for the presence of toxic elements.

TYPES OF INSTRUMENTS

Various types of instruments are available for determining oxygen level and the presence of dangerous air contaminants. Some of the most familiar instruments and their uses are described briefly.

Oxygen Deficiency

Both direct-reading instruments and manual techniques are available for sampling breathing air for oxygen content. Direct-reading instruments are preferred because they indicate the oxygen levels immediately and continuously.

These devices can be supplied with an alarm which is activated whenever the oxygen level drops below 19.5%.

The most widely-used oxygen detectors generate an electrical signal proportionate to the oxygen level. The detecting cell (sensor) can be built into the instrument, or can be connected by a cable for remote testing before entry into a confined space.

Combustible Substances

Both simple detectors and continuous monitors with alarms are available for measuring combustible gases and vapors. The most widely-used type of portable combustible gas analyzer is heat sensitive. When a combustible gas or vapor contacts the sensor, the flammable sample "burns" on a catalytic filament. This sensor responds to many combustible gases and is often used as a universal LEL (lower explosive limit) detection device.



Figure 11.1. Oxygen Deficiency Indicators. Rexnord Safety Products.



Figure 11.2. Combustible Gas Indicator. Rexnord Safety Products

Toxic Substances

With instruments that test for oxygen deficiency or for combustibility, it is best that the analyzer respond only to the substance in question and not to any background substances. However, when monitoring for toxic substances, response to other substances is just as important if these substances are also hazardous.

Detector Tubes

Colorimetric detector tubes containing solid reagent chemicals are frequently used for measuring toxic gases. There are tubes available for hundreds of atmospheric contaminants. The primary limitation in this type of testing is the lack of specificity in using certain detector tubes. Using the same reagent for different toxic substances sometimes limits their accuracy in mixed atmospheric environments. Detector tubes are limited too, by the fact that they do not test continuously.

Direct-Reading Instruments

Of the many types of direct-reading instruments commonly in use, some are provided with alarms and can therefore be used for continuous monitoring. This is distinctly advantageous in cases where a long period of time will be spent in the confined space, because work performed inside the space can alter the environment.

A widely-accepted type of instrument uses electrochemical cells. It can measure a number of toxic gases, such as carbon monoxide, hydrogen sulfide, sulfur dioxide, and oxides of nitrogen. These substances generate a current within the cell proportional to concentration of the gas.

INSTRUMENT: BIOMARINE MODEL 901 OXYGEN INDICATOR AND COMBUSTIBLE GAS INDICATOR²

The purpose of this instrument is to determine oxygen concentration and combustible gas levels.

It provides a simple method of determining oxygen concentrations and combustible gas levels, and is easily portable. The instrument is automatically temperature-compensated over its full range of 5°F to 110°F. It requires infrequent calibration and performs accurately in high-humidity environments. Calibration standards for the instrument are methane and hexane, although the instrument can detect other combustible gases as well.

Theory of Operation

A diaphragm pump assembly draws the sample to be analyzed through the filter assembly, sampling hose, water trap, and sensor assembly. The results are displayed on the percent oxygen and percent LEL meters. The figure is a system block

diagram showing the functional operation of the instrument.



Figure 11.3. Toxic Gas Indicator (Direct-Reading). Rexnord Safety Products.

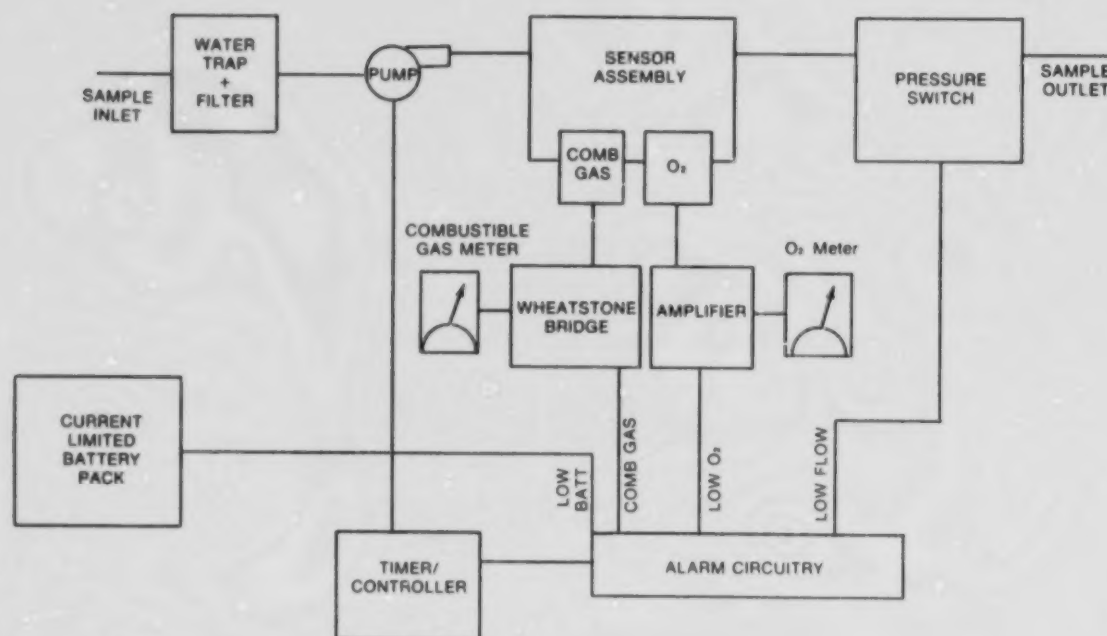


Figure 11.4. System Block Diagram. BioMarine Industries, Inc.

When this instrument is turned on, the pump starts almost immediately. Within four seconds, the sample passes through all the lines and filters to the sensors, and the displays are activated. After two more seconds, the alarms are engaged. This alarm delay allows for transient sensor behavior. When the sampling mode is selected, this start-up cycle is repeated in each sampling interval.

Precautions and Limitations

Model 901 should not be used to measure combustible gas either in oxygen-deficient atmospheres or in atmospheres containing more than 25% oxygen by volume. The battery must always be tested before the instrument is used.

In combustible gas concentrations above 100% LEL, the instrument will give incorrect readings. Tetraethyl lead or compounds containing silicon (sometimes used as lubricants or hydraulic fluids) may poison the instrument and prevent accurate readings. When the presence of these materials is suspected, the calibration of the unit must be tested daily.

Nomenclature

Figure 11.5 shows the displays and controls on the top of the instrument. The meter on the left side

indicates combustible gas in percent LEL hexane or percent methane. The meter on the right side indicates oxygen percentage and is also used to check the condition of the battery.

Three calibration pots are on the control panel. On the left side are zero and span adjustments for combustible gas. The oxygen span adjustment is on the right. A small jeweler's screwdriver is required to make these adjustments, which reduces the risk that settings will be changed in the field.

There are two toggle switches on the front panel. The left switch provides ON/OFF and mode select functions, allowing for continuous or periodic operation. The right switch turns the display meter lights on or off and tests the battery condition and alarm operation.

Two sealed plugs are for connecting a remote alarm and for plugging in the unit battery charger.

Between meters are found alarm lights indicating combustible gas, flow interruption, low battery voltage, and oxygen deficiency. An audible alarm built into the side of the case activates whenever any of the four lights is lit.

Operating Procedures

The instrument may be used as both a spotter and a monitor. Used as a spotter, it will determine oxy-

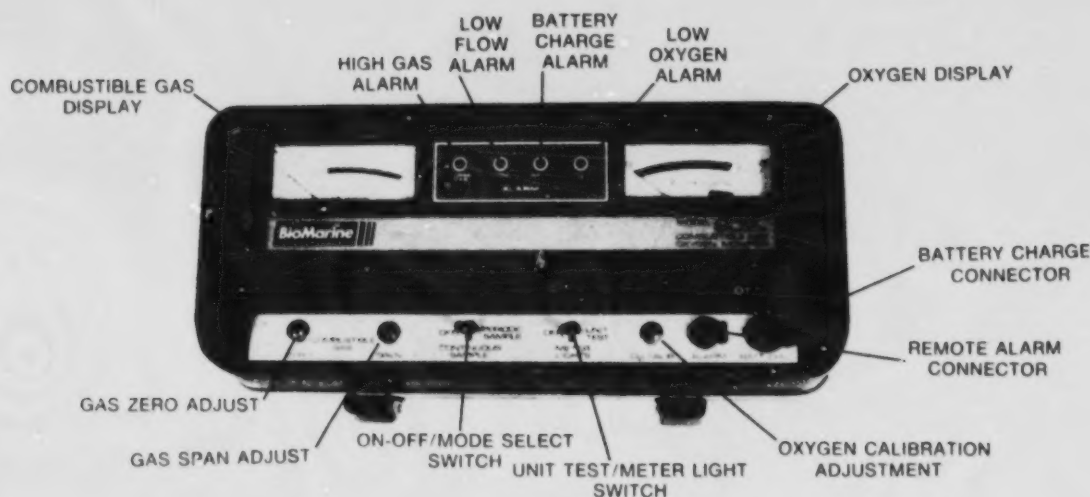


Figure 11.5. Controls and Displays. BioMarine Industries, Inc.

gen and combustible gas levels in a potentially hazardous environment before entry. In either capacity, it will activate both audible and visual alarms if either the oxygen level or the combustible gas level is dangerous.

To set up the unit, first remove the sampling hose, filter, and water trap from the storage area and connect to the unit as shown in the figure.

Turn the switch to **CONTINUOUS SAMPLE**. Wait four seconds. (Note: the unit should be tested in fresh air). The oxygen reading should be 21%. If it is not, the oxygen calibration pot should be adjusted to read zero.

The combustible gas reading should be zero. If it is not, the zero pot should be adjusted to read zero.

Hold the right hand toggle switch on **UNIT TEST**. All four alarm lights should be lit, the meters illuminated, the audio alarm operant, and the right-hand meter in the green battery band. If the battery reading is below the green band, either the battery must be recharged or a new battery pack must be inserted.

To test pump operation, place a thumb over the sample hose inlet. A slight vacuum effect and the activation of the flow alarm indicates the unit's readiness for use.

CAUTION: Before each day's use, sensitivity must be tested on a known concentration of meth-

ane, hexane, or other combustible gas or vapor equivalent to 20 to 50 percent of full-scale concentration. The unit must be accurate within plus or minus ten percent. Recalibration may be in order to restore accuracy. See section entitled "Calibration."

To operate, select either continuous or periodic operation. The periodic mode operates the unit at two-minute intervals of twenty seconds each. Battery life in this mode is extended to over seventy hours with the meter lights off and fifty hours with the meter lights on. In continuous operation, the instrument will run for over sixteen hours with the meter lights off and ten hours with the meter lights on.

Meter lights will be on as a result of the alarm test. To avoid running down the battery, these lights may be turned off after the test.

During operation, the alarm may flash when the oxygen level is too low. The alarm point is internally adjustable from 15-25%. It is normally set at 19.5%. The alarm may also flash when the combustible gas level is too high. The alarm point is internally adjustable from 0-50% LEL. It is normally set at 40% LEL.

Calibration

To check the calibration of the combustible gas sensor, a calibration kit is used. Connect the kit and

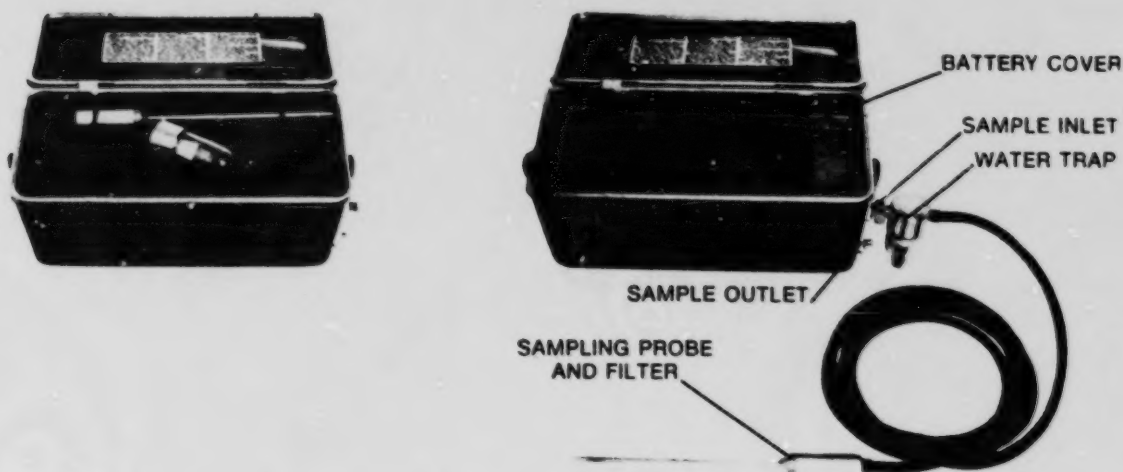


Figure 11.6 Sample Line Connection. BioMarine Industries, Inc.

balloon as shown in Figure 11.7. Adjust the gas flow so that the balloon is partially inflated with the pump on. When the meter reading reaches equilibrium, adjust to the correct value using the span pot. The combustible gas sensor is sufficiently stable that it does not require frequent calibration. However, daily calibration is recommended to assure optimum accuracy and safety.

Maintenance

A meter reading below the green battery band indicates that the battery is low. The battery may be recharged either inside or outside the unit.

To do so, first plug the battery charger into the front of the instrument. Then plug the charger module into a 115V socket (50 or 60 Hz). Charge the battery for eight to sixteen hours.

The oxygen sensor must be replaced when it can no longer be calibrated to 21% by adjusting the oxygen calibration screw.

To replace the sensor, remove the battery com-

partment cover. Unplug the battery jack and lift the battery from the chassis. Unscrew and lift the chassis assembly from the case. Refer to Figure 11.8 for correct sensor position.

Remove the connectors from the oxygen sensor and remove the sensor by unscrewing. Be sure to remember the correct arrangement of the color-coded wires.

Screw in the new sensor until a seal is made, and reconnect slide-on connectors.

Reverse the procedures to reassemble the unit. Then calibrate the sensor.

The combustible gas sensor, too, must be replaced when it can no longer be calibrated. Replacement of the combustible gas sensor follows the same procedure as that for oxygen sensor replacement.

A clogged filter is often the cause for flow alarm. In the event of flow alarm, all external lines and filters should fast be removed. The internal particulate filter will need replacement (see Figure 11.9 for details) if the alarm persists.



Figure 11.7. Calibration Set-up. BioMarine Industries, Inc.

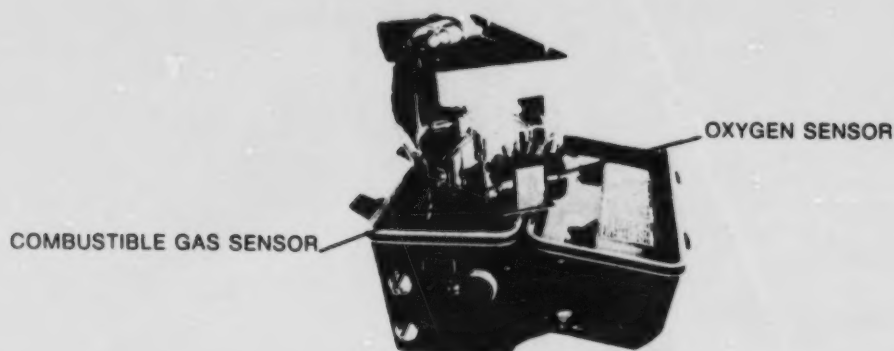


Figure 11.8. Sensor Replacement. BioMarine Industries, Inc.

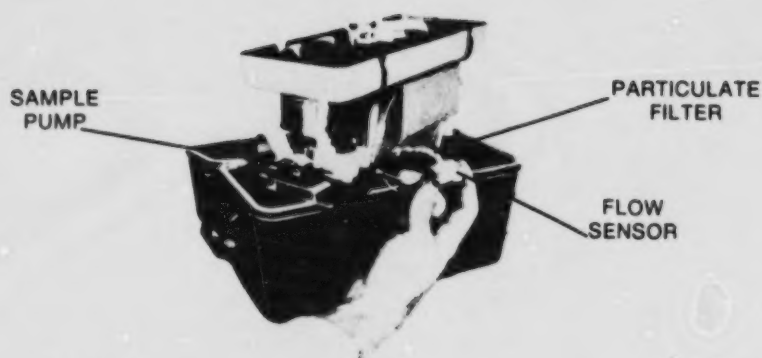


Figure 11.9. Particulate Filter and Pump. BioMarine Industries, Inc.

**INSTRUMENT: EXPLOSIMETER® MODEL 2A
COMBUSTIBLE GAS INDICATOR³**

The Model 2A is a portable instrument designed for quick determinations and measurement of combustible gases or vapors in air. It is for testing enclosed and confined areas.

It can sample the immediate environment or, by

use of sampling lines and probes, it can draw samples from remote areas such as manholes and tanks.

The instrument is factory-calibrated on pentane-in-air. Pentane calibration is used because it is representative of petroleum vapors and, when testing most other combustible gases, generally results in readings that are on the high (or safe) side.

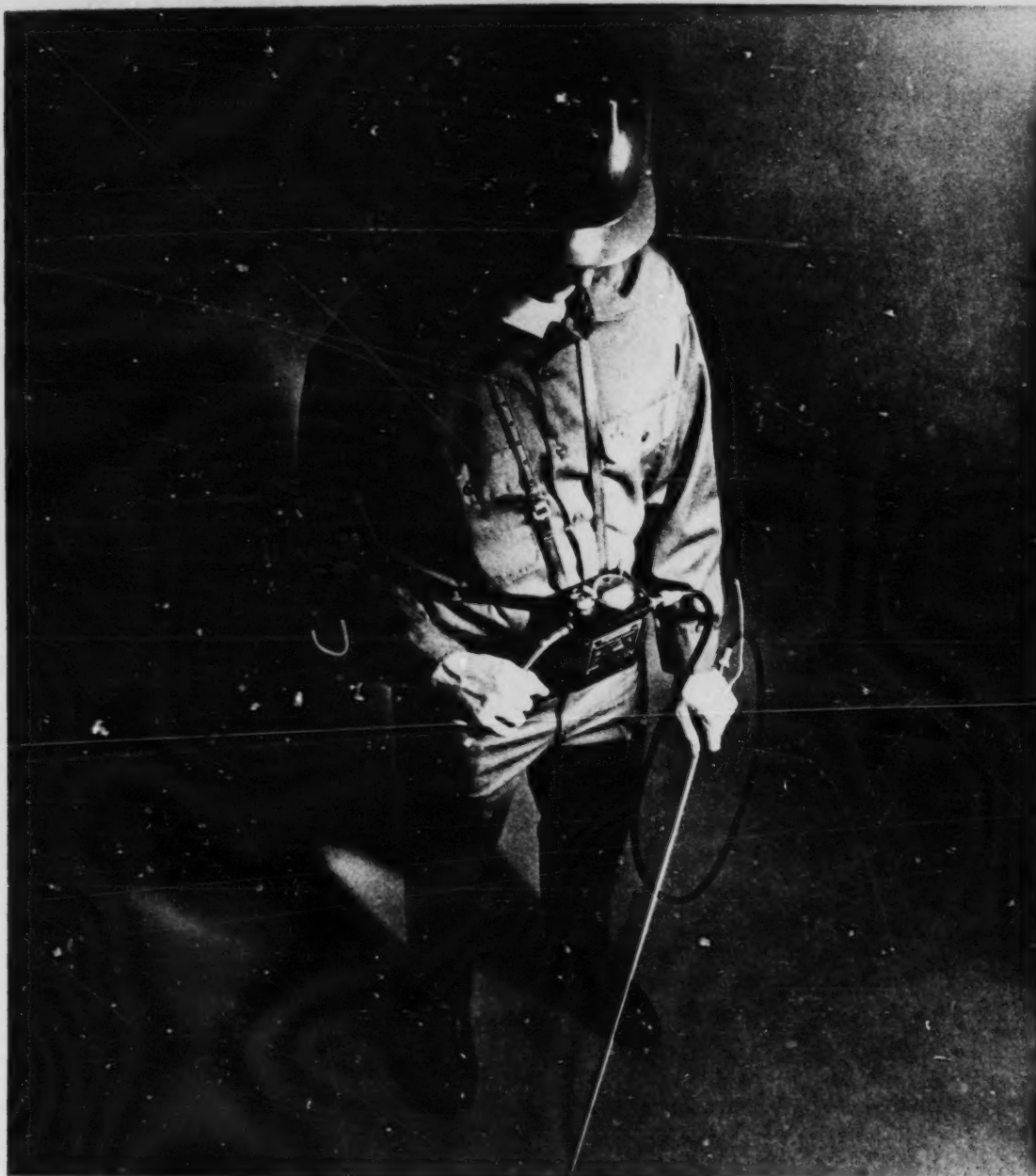


Figure 11.10. Model 2A, Combustible Gas Indicator with Sampling Line and Probe Rod. *Mine Safety Appliances Company.*

Theory of Operation

The Model 2A Explosimeter is an instrument by means of which an atmosphere may be quickly and conveniently tested for concentrations of flammable gases and vapors. It depends for its operation upon the heat developed by the actual combustion of the flammable portion of the sampled atmosphere. Tests are made with the instrument by drawing a sample of the atmosphere over a heated catalytic filament which forms part of a balanced electrical circuit. The current for this circuit is provided by six flashlight dry cells. Combustible substances in the sample are burned on the filament whose temperature is thereby raised and whose resistance is increased in proportion to the concentration of combustible substances in the sample. The electrical circuit is unbalanced, which causes a deflection of the meter pointer that indicates the concentration of combustible gases or vapors in the sample. The concentration scale is graduated in percent of the lower explosive limit.

The electrical bridge circuit of the instrument is designed so that its balance is established at the proper operating temperature of the detector filament. The circuit balance and detector current are adjusted simultaneously by the adjustment of a single rheostat. The proper relation between these two factors is maintained by a special ballast lamp in the circuit.

A schematic diagram of the electrical circuit and flow system of the instrument is shown in Figure 11.11. The sample is drawn through the filter chamber into the combustion chamber of the instrument by an aspirator bulb. Entering through the inlet flashback arrestor, the sample strikes a baffle plate, diffuses through the combustion chamber, contacts the detector filament, and leaves through the outlet flashback arrestor.

Precautions and Limitations

The Explosimeter is not designed for testing mixtures of hydrogen, acetylene, or other combustibles in which the oxygen content exceeds that of normal air.

The instrument has been designed as a general-purpose combustible gas indicator, intended to detect the presence of flammable gases and vapors. It is important that the information obtained by the instrument be interpreted with regard to the environment, industrial practice, and exposure. For example, an atmosphere that is indicated as non-hazardous from the standpoint of fire and explosion may, if inhaled, be toxic to workmen who are

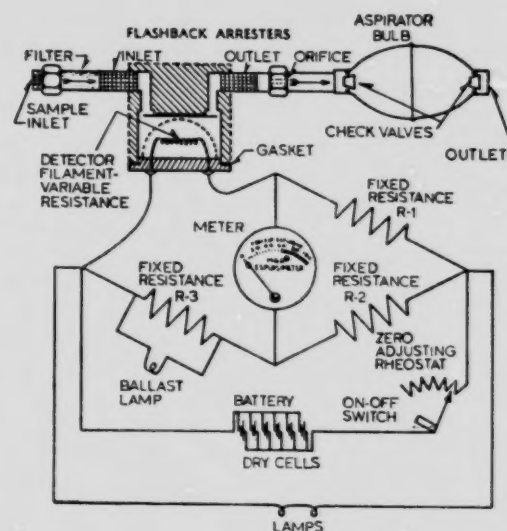


Figure 11.11. Schematic Flow System and Wiring Diagram. Mine Safety Appliances Company.

exposed for some time. Similarly, a confined space which is safe before work is started may be rendered hazardous by future operations. Frequent tests of questionable spaces while work is in progress are necessary during such operations.

The instrument will respond to gases or vapors drawn through the sampling system. If the combustible substance is a high boiling point solvent and is tested at normal ambient temperature, a relatively low vapor concentration will be shown by the instrument. If the container holding such solvents is subsequently heated (as by welding and soldering), the vapor concentration will increase, and thus the atmosphere of a vessel which was originally shown to contain only a low concentration of vapors may become explosive.

If an attempt is made to use such instruments for testing atmospheres contaminated with high boiling point solvents where the confined space is at a higher temperature than that of the instrument, it can be anticipated that there may be some condensation of the combustible vapors in the sampling line and in the flow system of the instrument; as a consequence, the instrument may indicate less than true concentration of vapors. For some such instances, condensation can be prevented by heating the sampling line and instrument to a tempera-

ture equivalent to or above that of the space to be tested; however, in no instance should these items be heated above 150°F.

The instrument will not indicate the potential explosive hazard of combustible gases and vapors when they are present in concentrations above their upper explosive limits.

Furthermore, the instrument has been designed to measure combustible vapors in air. It cannot measure the percentage of vapors in steam or inert atmospheres, due to the absence of oxygen necessary for combustion on the instrument detector unit. For a test of combustibility, the steam or inert gas must be displaced with air.

The instrument will not indicate the presence of explosive or combustible mists or sprays such as lubrication oil, or explosive dusts such as grain or coal dust.

When sampling over liquids, care should be taken that the end of the sampling line does not touch the surface of the liquid. It is recommended that a probe tube be used in tests of this character to prevent the liquid from being drawn into the sampling tube.

Oxy-hydrogen and Oxy-acetylene Mixtures

The Model 2A Explosimeter is not designed for testing mixtures of hydrogen, acetylene, or other combustibles, in which the oxygen content exceeds that of normal air (oxygen-enriched atmospheres). Special instruments are available for these applications.

Testing Atmospheres Contaminated with Leaded Gasoline

When an atmosphere contaminated with leaded gasoline is tested with an explosimeter, the lead produces a solid product of combustion which may develop a coating on the detector filament that may decrease its sensitivity. To reduce this possibility, a filter is available for use in place of the normal cotton filter in the instrument. This device reacts with the lead vapors to produce a more volatile lead compound.

NOTE: Silanes, silicones, silicates, and other compounds containing silicon in the tested atmosphere may seriously impair the response of the instrument. Some of these materials rapidly "poison" the detector filament so that it will not function properly. When such materials may be in the atmosphere, the instrument must be checked frequently (at least once every five tests). A calibration test system is available for conducting the test.

The calibration test system can also be used periodically to check the instrument calibration. If the instrument reads low on the test gas, immediately replace the filament and the inlet filter and re-test.

Operating Procedures

The Explosimeter is set in its proper operating condition by the adjustment of a single control. This control is a rheostat regulating the current to the explosimeter measuring circuit. The rheostat knob is held in the "OFF" position by a locking bar. This bar must be lifted before the knob can be turned from the "OFF" position.

To prepare the Explosimeter for operation, select an area known to be free of combustible gases or vapors.

Lift the end of the rheostat knob one-quarter turn clockwise.

This operation closes the battery circuit. Because of unequal heating of circuit elements, there will be an initial deflection of the meter pointer. The meter pointer may move rapidly upscale and then return to a point below ZERO, or it may drop directly below ZERO.

Flush fresh air through the instrument.

The circuit of the instrument must be balanced with air free of combustible gases or vapors surrounding the detector filament. Five squeezes of the aspirator bulb are sufficient to flush the combustion chamber. If a sampling line is used, an additional two squeezes will be required for each ten feet of line.

Adjust the rheostat knob until the meter pointer rests at ZERO.

Clockwise rotation of the rheostat knob causes the meter pointer to move up the scale. A clockwise rotation sufficient to move the meter pointer considerably above zero should be avoided.

The meter scale is red above sixty to indicate that gas concentrations within this range are nearly explosive. Workers should not be allowed to work in atmospheres testing within this range.

To turn the instrument off, rotate the rheostat knob counterclockwise until the arrow on the knob points to "OFF." The locking bar will drop into position in its slot, indicating that the rheostat is in the "OFF" position.

The terminal voltage of dry cells gradually decreases as the cells are used. This drop in voltage takes place most rapidly in the first few minutes after the current is turned on. The balance of the Explosimeter circuit is dependent upon the applied voltage, and therefore gradually changes as the



Figure 11.12. MSA Model 2A, Explosimeter. Mine Safety Appliances Company.

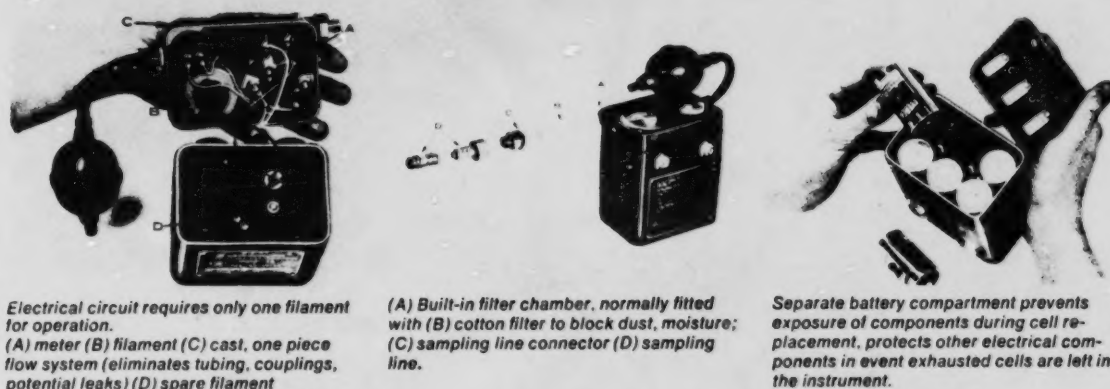


Figure 11.13. MSA Mode 2A, Explosimeter. Mine Safety Appliances Company.

instrument is in operation. With freshly installed batteries the balances may be expected to change approximately 5% (one scale division) in five minutes. After ten to twenty minutes of use, the shift of the balance setting should not exceed 1% (1/5 scale division) in five minutes.

When it is possible to do so, the bridge circuit balance should be checked before each test. If this is not practical, the balance adjustment should be made at three-minute intervals during the first ten minutes of testing and every ten minutes thereafter.

Special Sampling Applications

The dilution tube is for tests where concentrations of combustible gases in excess of lower explosive limit concentrations (100% on the instrument meter) are to be compared, such as in testing bar holes in the ground adjacent to a leak in a buried gas pipe, or in following the purging of a closed vessel that has contained flammable gases or vapors, a special air-dilution tube is available. Such dilution tubes are available in 1:1, 10:1, and 20:1 ratios of air to sample. Thus, rich concentrations of gas can be compared.

The dilution tube is connected by screw threads between the intake of the instrument and the end of the sampling line which is normally attached directly to the instrument. It is therefore necessary in all tests made with the dilution tube attached to the instrument that the instrument be operated in

fresh air and that the gaseous sample be delivered to the instrument through the sampling line. This permits a comparison of a series of samples beyond the normal range of the instrument, to determine which sample contains the highest concentration of combustible gases. This tube also makes it possible to follow the progress of purging operations where a combustible atmosphere is being replaced with inert gases.

Pressure Testing Bar Holes

In some instances where bar holes are drilled to locate pipe line leaks, a group of holes, all containing pure gas, may be found. This condition usually occurs near a large leak. The gas pressure will be greatest in the bar hole nearest the leak. The instrument may be used to locate the position of the leak by utilizing this bar hole pressure. This is done by observing the time required for this pressure to force gas through the instrument sampling line. A probe tube equipped with a plug for sealing off the bar hole into which it is inserted is required. The following test procedure should be followed.

Fresh air is aspirated through the Explosimeter and the aspirator bulb coupling is unscrewed. This removes the flow regulating orifice from the instrument. Adjust the rheostat until the meter pointer rests on ZERO.

The probe tube is now inserted in the bar hole and sealed off with the plug. Observe the time at which this is done. Pressure developed in the bar

hole will force gas through the sampling line to the instrument. This will be indicated by an upward deflection of the meter pointer as the gas reaches the detector chamber.

Determine the time required for the gas to pass through the probe line. The bar hole showing the shortest time will have the greatest pressure.

When the upward deflection of the meter pointer starts, turn off the instrument, replace the aspirator bulb, and flush out the probe line for the next test.

Calibration

A calibration test assembly is available to check the Explosimeter periodically with a known concentration of methane-in-air. The Explosimeter calibration should be checked after replacement of the filament, ballast lamp, or flashback arresters, after prolonged periods of non-use, or in the event that catalytic "poisons" are indicated in the sample.

Maintenance

The pointer on the rheostat knob indicates approximately the condition of the dry cells. When the circuit is properly balanced with fresh cells, the pointer on the rheostat knob should be directed toward the left edge of the instrument.

When the meter pointer remains below ZERO and cannot be brought up to ZERO even when the control rheostat is turned to its extreme clockwise position (with the knob pointer directed at the right edge of the case), the cells are exhausted and must be replaced.

The dry cells are replaced by removing the bottom of the instrument case which is held in place by two slotted screws. The cells operate in parallel and must be installed with the tops (positive terminal) toward the top of the battery compartment.

The cells should be replaced in groups. Do not use partially discharged cells with new cells.

Detector Unit

The detector filament of the Explosimeter is made of platinum. The life of the detector unit depends greatly upon the concentrations of gases tested. When the majority of samples tested contain not more than 50% of the lower explosive limit, a detector filament will serve for several thousand tests. When higher concentrations, especially those above the lower explosive limit (above 100% on the explosimeter scale) are frequently encountered, the life of the detector unit will be shortened. It is advisable, when gaseous concentrations above the scale

range of the instrument are indicated, to stop sampling and flush the Explosimeter with fresh air.

If the pointer of the indicating meter moves to the extreme right side of its scale when the instrument is turned on, and cannot be adjusted to ZERO, the detector filament may be burned out. It should be replaced.

A spare detector unit is located inside the case of the instrument below the panel and may be made accessible by removing the three screws that hold the panel in place.

Replacement of Detector Unit

Remove the top of the Explosimeter case. Remove the screws holding the two green wires to the terminals in the top of the bakelite head of the detector unit. Unscrew the unit from the combustion chamber. Screw the replacement detector unit tightly into the combustion chamber. The gasket should be clean and properly seated.

When the green wires leading to the terminals on the top of the detector head are replaced, care should be taken that the screws holding them are firmly set and that the two terminal lugs at the ends of the wires do not touch each other.

Provisions should be made to replace the spare filament in the receptacle inside the case, so that in the event that another filament burns out while the instrument is being used in the field, a spare will be available.

Ballast Lamp

The MSA Explosimeter uses a special electrical bridge circuit of "controlled stability." This feature makes it practical to adjust the circuit balance and the detector operating temperature with a single operating control. The function of the ballast lamp is to regulate the circuit stability.

The lamp should always be kept firmly screwed into its socket and never removed from it. It will generally last throughout the life of the instrument.

The filament of the ballast lamp in a properly operating instrument, therefore, does not glow brightly; its dimness does not indicate a malfunction of any sort.

Replacement is required only in the case of breakage or after it has been subjected to severe mechanical shock.

Flashback Arresters

The flashback arresters are located in the inlet and in the outlet of the detector filament chamber. The inlet arrester is reached by removing the detector filament and the baffle plate at the bottom of

the detector chamber. The outlet flashback arrester is reached by removing the aspirator bulb coupling.

The arresters are made of cadmium-plated copper screen tightly wrapped upon a rod. They may be removed by pulling this rod with a pair of long-nosed pliers. If they are clogged, they should be replaced with new ones. The flashback arresters are inexpensive and their continual function is so important that any attempt to clean them is not recommended.

NOTE: Always be sure that both arresters are in their places and that they fit snugly before the instrument is reassembled. The flashback arresters are important, since they prevent the possibility of flame propagation from the combustion chambers.

The Flow System

The normal rate of sample flow through the instrument is 0.030 to 0.050 cubic feet per minute. The indication of the instrument is practically independent of the rate of sample flow within wide limits. To check for leaks in the flow system, close the inlet of the instrument with one finger of the left hand, then depress the aspirator bulb. Immediately seal the aspirator bulb outlet with one finger of the right hand. As long as both fingers are held in place, the bulb should remain deflated. If the bulb fills, there is a leak in the flow system, which includes the filament, aspirator bulb, and the inlet and outlet fitting gaskets. To check the aspirator exhaust valve for leakage, close the inlet of the instrument with one finger of the left hand; then depress the aspirator bulb. The bulb should not completely inflate in less than six seconds.

To check for flow (after checking for leaks), depress the aspirator bulb without blocking either intake or exhaust. The bulb should fill completely in one to two seconds.

Flow Regulating Orifice

An orifice controlling the rate of flow through the Explosimeter is located in the aspirator bulb coupling. It may be screwed out after the rubber tubing connection to the bulb is removed. It is made of a special non-corrosive material. If it becomes clogged, it may be cleaned by pushing a fine wire through its opening.

Filter Chamber

The Explosimeter has a filter chamber integrally cast in the case. It is reached by unscrewing the sampling line coupling. A cotton filter should be inserted to remove dust or liquid from the incoming sample. An activated charcoal filter should be

used to differentiate between illuminating gas and petroleum vapors. The petroleum vapors are absorbed by the activated charcoal.

An inhibitor filter must be used when the atmosphere contains or is suspected of containing vapors of leaded gasoline.

Meter

If the mechanical ZERO setting of the meter has been disturbed in transport or by accident and the meter pointer is not on the ZERO line when the instrument is "OFF," set the pointer to ZERO by slowly turning the screw on the meter face with a small screw driver.

At the end of a series of tests, the instrument may be flushed by aspirating fresh air in to eliminate traces of combustible vapors that may have been absorbed.

After periods of idleness or considerable operation in severely corrosive atmospheres, the contacts of the rheostat may become tarnished, causing erratic response to the operating control. This may be corrected by removing the batteries and turning the operating control back and forth a number of times.

INSTRUMENT: MSA MODEL R CHECK KIT (CALIBRATION TEST SYSTEM)⁴

This calibration check kit, Model R, provides a quick method of checking the response of portable gas instruments. With the appropriate container of calibration check gas, it may be used with a variety of MSA portable instruments. In this unit, we will discuss its use for calibrating the MSA Model 2A Explosimeter.

Before the calibration can be checked, the instrument and its aspirator sampling bulb must be in operating condition as described in the appropriate section of this unit.

Attach the flow control to the calibration gas tank.

Connect the adapter-hose to the flow control and to the inlet fitting of the instrument.

Open the flow control valve.

Record the meter reading after it stabilizes. NOTE: It is not necessary to operate the aspirator bulb to obtain the calibration sample. Depending on which calibration gas is used, the instrument reading should be within one of the following ranges:

Instrument	2.0% Methane	2.5% Methane
Model 2A	42 to 60%	54 to 70%
Model 53	40 to 51%	53 to 68%
Model 62	60 to 75%	



Figure 11.14. Model R, Calibration Check Kit. Mine Safety Appliances Company.

If the instrument does not read within the acceptable range, replace the detector filament unit and repeat the calibration check procedure. *See applicable instrument instruction section for complete service details.*

Close the flow control valve.

Remove the adapter-hose from the flow control and the inlet fitting on the instrument.

Remove the flow control from the calibration gas tank. **NOTE:** Calibration gas tank contents are under pressure. To prevent possible ignition, use no oil, grease, or flammable solvents on the flow control or the calibration gas tank. In order to pre-

vent possible rupture of the tank, do not store near heat or fire. When the tank is exhausted, discard safely, such as by burial in the earth or in a sanitary land fill. Do not throw into a fire or incinerate. Do not puncture. It is illegal and hazardous to refill the gas tank.

**INSTRUMENT: BIOMARINE MODEL 500
CARBON MONOXIDE DETECTOR**

Model 500 is designed to provide precise readings of the carbon monoxide (CO) level quickly in a wide range of environmental conditions. Model 701 detects hydrogen sulfide (H_2S).



Figure 11.15. Model R, Calibration Check Kit with Model 100 Combustible Gas Alarm. Mine Safety Appliances Company.

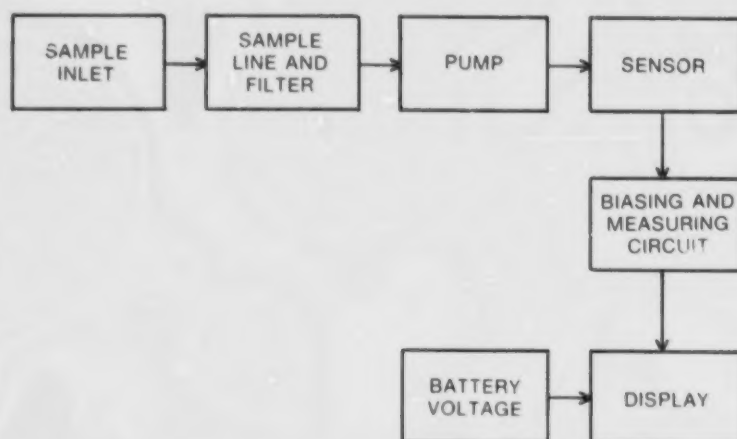


Figure 11.16. System Block Diagram for Model 500. BioMarine Industries, Inc.

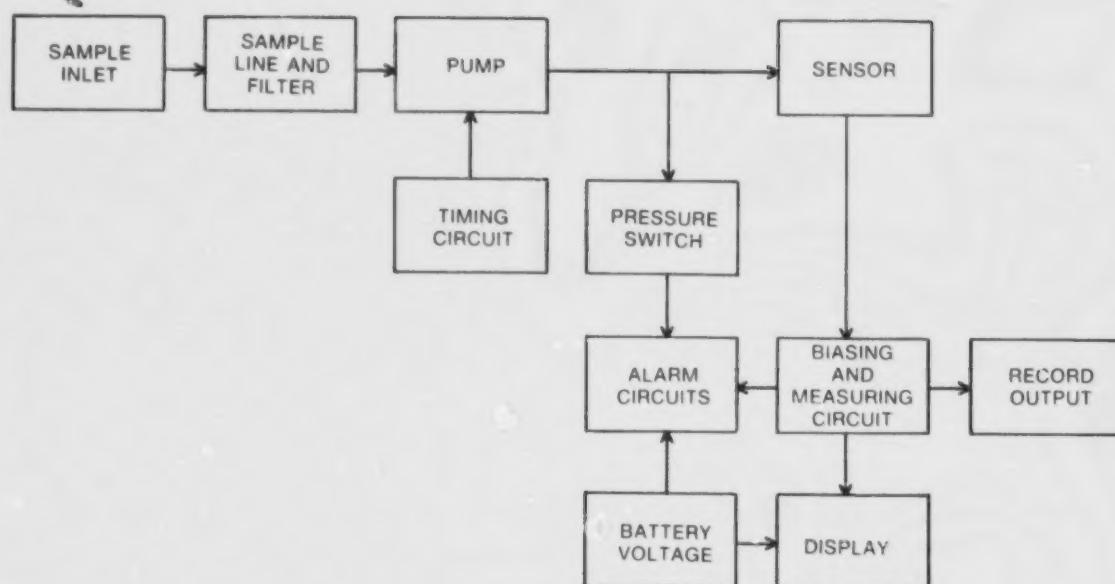


Figure 11.17. System Block Diagram for Model 701. BioMarine Industries, Inc.

MODEL 700 HYDROGEN SULFIDE MONITOR⁵

Each instrument has an audio/visual alarm system, a capability for continuous or periodic sampling, and remote recording and alarm connections

Theory of Operation

Both detectors use an electric-chemical sensor. A diaphragm pump assembly draws the sample to be analyzed through the filter assembly and sampling line to the sensor. CO or H₂S molecules diffuse through a Teflon barrier and are oxidized at a polarized sensing electrode. The sensing electrode is maintained at a constant potential with respect to a highly reversible counter electrode. Both electrodes are immersed in a sulfuric acid electrolyte. An electric current is generated, proportional to the gas concentration. This current is electronically sensed and displayed as CO or H₂S ppm on the front panel meter. Figure 11.16 is a system block diagram of Model 500. These instruments have alarms which are activated when the battery requires charging or the gas level has exceeded a pre-set level. A flow alarm is controlled by a pressure switch. There are both pulsed and steady alarm indications. The pulsed or flashing alarm indicates a hazardous situation due to the gas level. The

steady alarm indicates an instrument malfunction due to interrupted flow or low battery voltage.

Precautions and Limitations

The battery condition and pump operation must be tested before the monitor is used. If the battery has been discharged, the unit should be given sufficient time to establish the required charge on the sensor. The required time is related to the time during which the unit was in the LOW BATTERY condition. Readings can be made an hour after battery charging begins. Maximum accuracy requires twenty-four hours' sensor stabilization. Do not store the instrument for longer than two months without recharging the battery.

Under no circumstances should the sensor be disassembled. It contains sulfuric acid. If acid should get on the skin, flood with plenty of water; then apply a solution of water and baking soda.

Nomenclature

Figure 11.18 is a view of these models from the top, showing the display and controls. The meter scale is calibrated in 0-100 and 0-500 parts per million carbon monoxide. The scale range is selected by a slide switch located directly beneath the meter. The meter is also used to check the battery voltage.

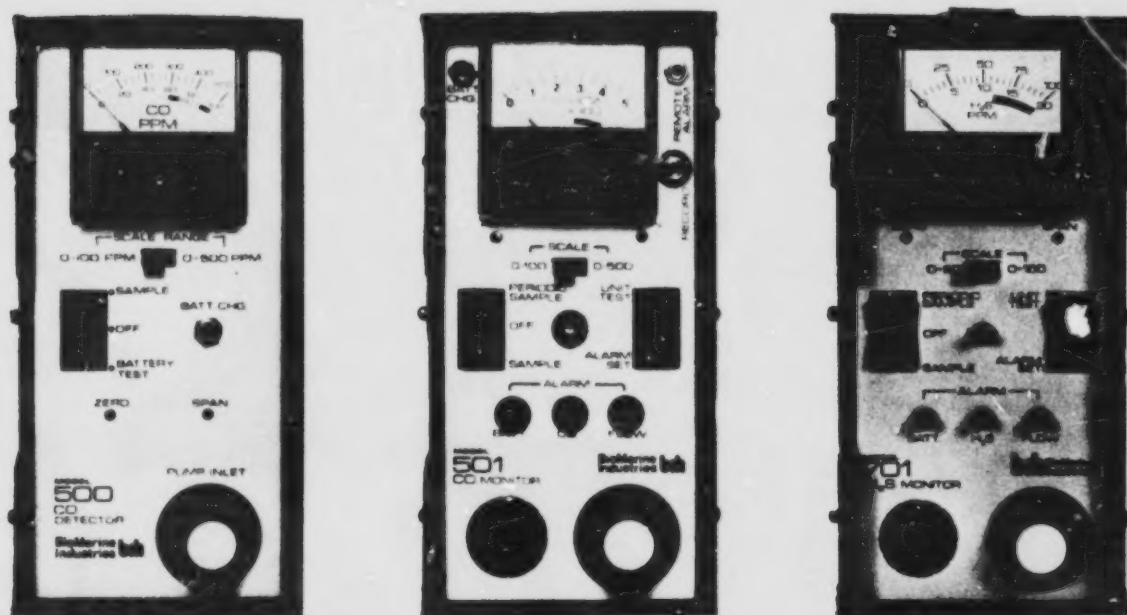


Figure 11.18. Controls and Displays. BioMarine Industries, Inc.

Model 500 has a single rocker switch which is used both to test the battery condition and to turn the unit on and off. The left switch is the ON/OFF and MODE SELECT switch. This switch enables selection of either continuous or periodic sampling. The right switch is used to test battery conditions and alarm operation. It may also be used to display the alarm level. A yellow light indicates pump operation.

Alarms are activated whenever the carbon monoxide or hydrogen sulfide level exceeds the preset alarm level, whenever the sample flow ceases due to line clogging or kinking or pump failure, or whenever the battery requires recharging.

Two recessed calibration adjustments are available. A small jeweler's screwdriver is required to make both zero and span adjustments. This minimizes the possibility that settings will be changed in the field.

Operating Procedures

To set up the instrument, connect the sampling hose and filter as shown in Figure 11.19. Switch to battery test or unit test. The meter should read in the green band. If not, recharge the battery. Full recharge requires sixteen hours.

CAUTION: Before each day's use, the sensitivity must be tested on a known concentration of carbon monoxide or hydrogen sulfide. Accuracy must be within plus or minus 10% of actual value. If it is not, the unit must be recalibrated.

To test the pump operation, place a thumb over the end of the sampling hose. A slight vacuum should be felt and the pump should labor. To measure unknown carbon monoxide or hydrogen sulfide concentrations, place the end of the sampling probe in the environment to be monitored and latch the rocker switch in the sample position for twenty seconds or until the highest steady reading is

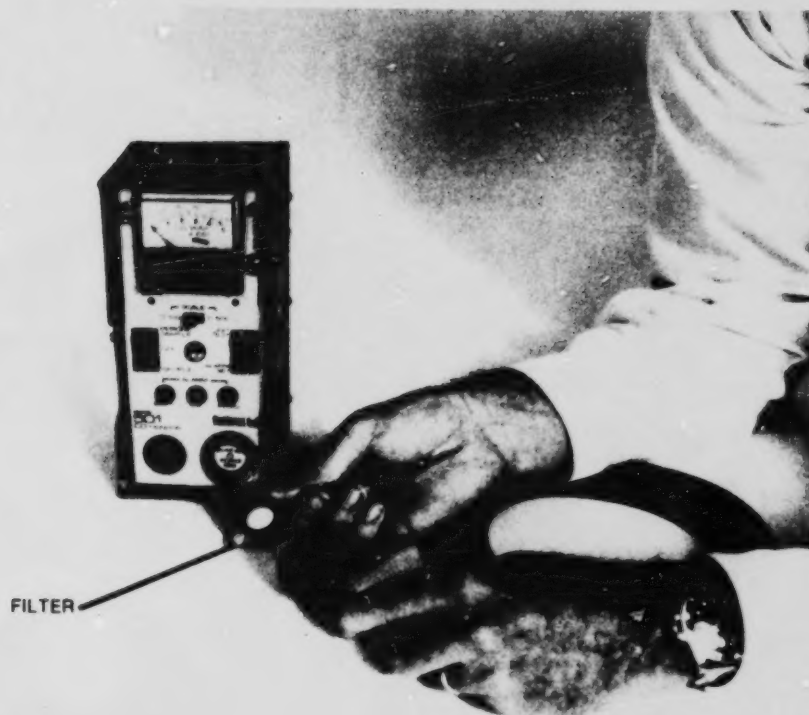


Figure 11.19. Sample Line. BioMarine Industries, Inc.

obtained. The sampling hose need not be connected for area monitoring. However, the filter must be in place whenever the pump is operating.

Table 11.1 shows the relative response of interfering gases on the CO detector and the response of these gases on the H₂S detector. To eliminate the effect of some of these gases, filters are available for the carbon monoxide detectors. These filters are inserted in place of the particulate filter shown in Figure 11.19. Table 11.1 also shows the response

with a CO interfering gas filter in place. An interfering gas filter is not necessary unless the user suspects the presence of another gas and wants to protect the CO detector from that gas. Note that some of the interfering gases are also highly toxic.

Calibration

Expose the sampling probe to fresh air, and latch the rocker switch in the sample position. After twenty seconds, turn the zero adjustment until the meter reads zero.

Table 11.1
USE IN PRESENCE OF INTERFERING GASES.

Interfering Gas and Concentration Tested	Reading on Scale of Model 701 H ₂ S Detector	Model 500, 501 CO Detectors With CO Interfering Gas Filter #189	Reading on Scale of Model 500, 501 CO Detectors
Acetone 930 PPM	6	5	19
Acetylene 57 PPM	12	25	140
Ammonia 1140 PPM	3	4	5
Acrylonitrile/Nitrogen 1100 PPM	3	16	4
Benzene 900 PPM	3	4	4
1,3 Butadiene 960 PPM	490	455	1330
Butane 1090 PPM	3	5	5
Butane 900 PPM	6	5	30
Chlorine 70 PPM	4	3	17
Chloroform 1020 PPM	7	17	19
Cyclohexane 1100 PPM	3	3	3
Ethane 113 PPM	3	7	8
Ethylene 100 PPM	6	10	70
Ethylene Dichloride 1030 PPM	4	7	25
Ethylene Oxide 14300 PPM	525	1260	1400
Formaldehyde 1100 PPM	3	7	100
Freon-21 927 PPM	3	6	9
Heptane 4000 PPM	5	4	11
Hexane 4600 PPM	4	0	10
Hydrogen 915 PPM	17	65	65
Methane 3850 PPM	3	5	16
Methyl Chloride 1100 PPM	3	7	15
Methyl Mercaptan 23 PPM	157	3	165
Nitric Oxide 96 PPM	350	47	630
Nitrogen Dioxide 69 PPM	—1	10	157
Nitrous Oxide 504 PPM	2	7	4
Propane 10000 PPM	3	4	6
Propylene 1070 PPM	100	25	875
Sulfur Dioxide 52 PPM	90	10	154
Toluene 1030 PPM	3	5	8
Trichlorethane 900 PPM	10	7	45
Trichlorethylene 925 PPM	4	252	15
Vinyl Chloride 940 PPM	5	25	100

BioMarine Industries, Inc.

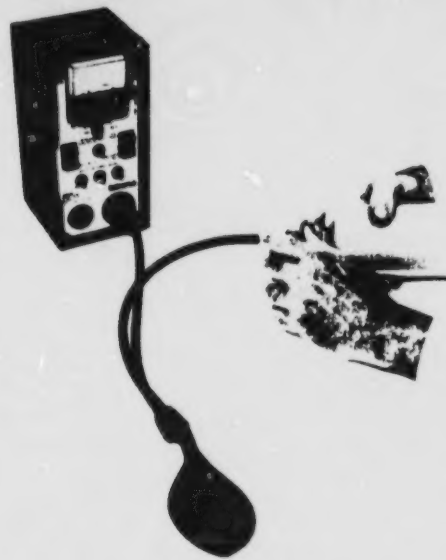


Figure 11.20. Calibration Set-Up. *BioMarine Industries, Inc.*

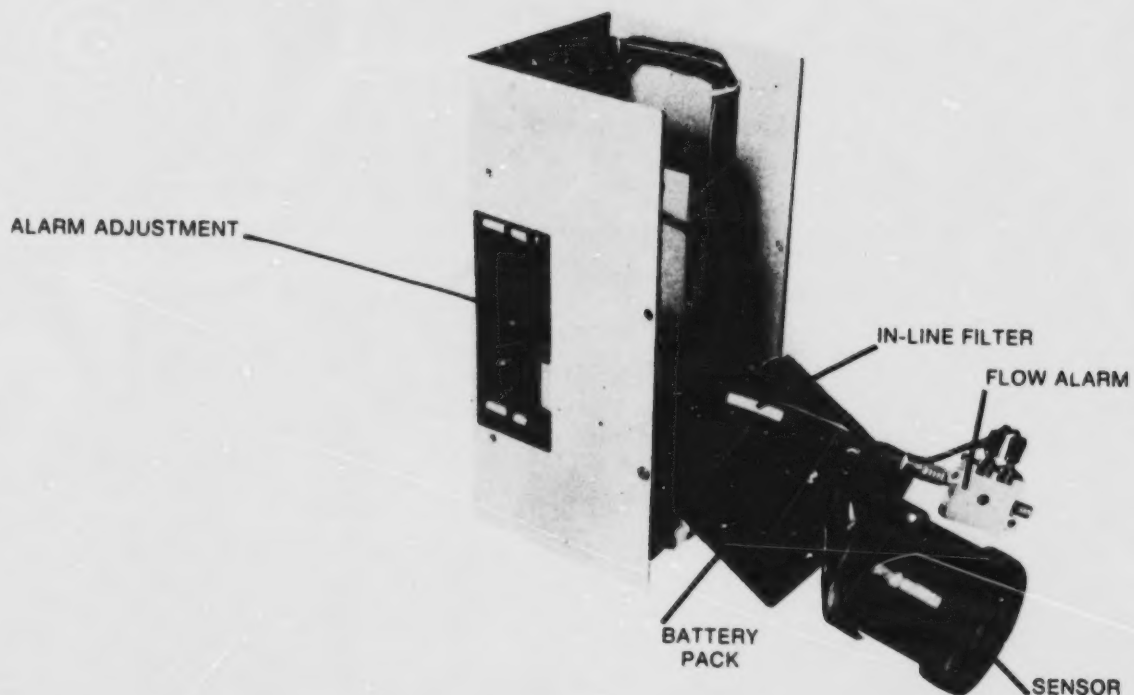


Figure 11.21. Chassis Assembly. *BioMarine Industries, Inc.*

Span Adjust

The sensor may be exposed to a known concentration of carbon monoxide or hydrogen sulfide by connecting the calibration kit and balloon. Adjust the calibration gas flow so that the balloon is partially inflated with the pump on. When the meter reading has come to equilibrium (about twenty seconds), adjust to the correct value using the span adjustment.

Maintenance

Sensor replacement—When the sensor can no longer be calibrated by adjustment of the zero or span pot, it can be assured that the useful life of the sensor has terminated and that it should be replaced. To replace the sensor, remove the four screws holding the chassis in the leather case and lift out the chassis.

Remove the upper two screws from the battery housing and swing the sensor and battery assembly out.

Remove flexible tubing and color coded leads from the sensor.

Unscrew the bracket from the battery pack and sensor.

Reverse these steps to install the new sensor, taking care to install wires according to color code, yellow to yellow, green to green, and blue to blue. Do not overtorque the screws when securing the bracket to the battery pack.

Flow Test

In order to test pump and lines, repeat the first two steps. Unplug the sampling line from the sensor and check that flow occurs. If the filters in the lines appear dirty, they must be replaced.

Notes

1. Adapted from *A Primer on Confined Area Entry*, a pamphlet prepared by Rexnord Safety Products, Malvern, PA.
2. Adapted from the BioMarine Model 902 Combustible Gas/Oxygen Monitor operational manual.
3. Adapted from the Mine Safety Appliances Company Explosimeter Combustible Gas Indicator Model 2A instruction manual and complementary Data Sheet 08-00-28.
4. Adapted from the Mine Safety Appliances Company Calibration Test System Model R check kit instruction manual and complementary Data Sheet 08-00-28.
5. Adapted from the BioMarine Industries operation manual for Models 500 and 501 (CO monitors) and Model 701 H₂S monitor).

UNIT 12

VENTILATING CONFINED WORKSPACES

INTRODUCTION

Once the contractor determines that a confined workspace contains an atmosphere which is flammable, toxic, and/or oxygen-deficient or enriched, he must take immediate action to ventilate the space and make the atmosphere safe for work before any worker is allowed to enter.

PROPERTIES OF AIRBORNE MATERIALS¹

Before we move on to discuss in detail the types of ventilation systems, let us first take a look at the forms of contaminants found in the atmosphere.

Dusts are solid particles generated by handling, crushing, grinding, and detonation of organic and inorganic materials. Dust particles five microns or smaller are the most hazardous, because they are most able to reach the lungs; larger particles are filtered out in the nasal passages or other parts of the respiratory system.

Fumes are small, solid particles created by condensation from the gaseous state. They are usually only fractions of a micron in size.

The trait characteristic of most fumes is their tendency to flocculate and coalesce. Very small spherical fume particles tend to attach themselves together in long chains or clumps of particles.

Mists are suspended liquid droplets generated by condensation from the gaseous to the liquid state or by breaking up a liquid into a dispersion such as by splashing, foaming, and atomizing.

Smoke is the aerosol mixture resulting from incomplete combustion of carbonaceous material such as coal, oil, tar, and tobacco.

Vapors are the gaseous forms of substances which are normally in the liquid or solid state and which can be changed to the vaporous state either by an increase in pressure or by a decrease in temperature.

Gases are normally compressible, formless fluids occupying the space of an enclosure. These fluids can be changed to the liquid or solid state by the effect of increased pressure or decreased temperature.

Effective Specific Gravity

Hazardous dusts, fumes, vapors, and gases are airborne, following air currents, and are not necessarily subject to appreciable motion, either upward or downward, because of their own density.

VENTILATION

Before a confined workspace is ventilated, the contractor should establish a work plan for controlling ventilation activities.

The most effective means of ventilating a confined space is by introducing fresh air near the bottom of the space and discharging it near the top. Any system of positive ventilation must maintain constant flow of fresh air through all areas of the space.

If the confined space is a tank or vessel constructed of lightweight metal, it could collapse during ventilation. The air flow should therefore be carefully controlled, or a low-suction-pressure air mover should be used.

Pure oxygen should never be used to ventilate a confined space, since oxygen concentrations in excess of twenty-one percent may significantly increase the combustibility of other substances in the space.

Ventilation may be accomplished by natural, mechanical, or steam methods.

Natural Ventilation is done by removing roof and side covers and allowing the natural air currents to remove the gases or vapors. Due to the unpredictable direction in which the vapors may drift, no work should be done in the area until tests show that the area is free of the hazard.

Natural ventilation is generally insufficient to achieve an adequate exchange between the contaminated air inside the space and fresh air outside the space. This is particularly true in confined spaces with limited-access openings. Ventilation provided by air-moving devices is a much more effective means of removing contaminated air from a confined or enclosed space, introducing clean respirable air into a space, and controlling the level of hazards either created by contaminants in the

space or evolved from operations conducted within the space.

Mechanical ventilation. One method of mechanical ventilation is to use an approved fan installed above the confined workspace. This has the advantage of dispersing the vapors to the atmosphere at a high level.

Another method is to install a blower at ground level blowing air into the tank. In this case, the electrical equipment should be explosion-proof unless it is located well away from possible areas of vapor travel.

Steam ventilation. When steam is used to ventilate a confined workspace, it should be introduced through a connection at or near the bottom of the space. Covers should remain open during the steaming period. To be effective, the temperature of the space atmosphere should be raised to at least 170°F. Steam ventilation is not considered advisable for large tanks or during cold weather. The steam nozzle should be bonded to the space to prevent static electricity buildup, and all parts of the space should be grounded.

Classification of Ventilating Systems

Ventilation can be accomplished by one or both of two methods. Dilution (or general) ventilation dilutes the concentration of the contaminant before it reaches the breathing zone by mixing with uncontaminated air. Local exhaust and ventilation captures and removes the contaminant at or near its source, thus preventing the release of the contaminant into the workspace. Dilution ventilation does not reduce or eliminate the total amount of hazardous material released into the workspace air as does local exhaust ventilation. Therefore, local exhaust ventilation is normally the preferred and more economical method for contaminant control.

There is often some confusion between the two types of ventilation systems. One way to distinguish the two is to remember that dilution ventilation will release an exhaust air stream whose concentration of contaminant is not significantly higher than that of the general atmosphere within the confined space; the exhaust air stream from the local exhaust system, on the other hand, will have a concentration of contaminant significantly higher than that of the general atmosphere within the confined space.

Dilution Ventilation

In dilution ventilation, the confined space is flushed by supplying and exhausting large volumes

of air throughout. Properly used, dilution ventilation can be very effective for removing large volumes of heated air or for removing low concentrations of non-toxic or low-toxicity contaminants from minor and centralized sources. Dilution ventilation is achieved by either natural or mechanical means. Often the best overall result is obtained with a combination of mechanical and natural air supply with mechanical and natural exhausters.

Dilution ventilation may be utilized in a confined workspace to provide uncontaminated respirable air for breathing, and to maintain the general comfort of personnel. It may also suffice for maintaining concentrations of toxic and flammable atmospheres at acceptable levels where the sources of such contaminants are small and/or where the evolution of airborne contaminants is low. The accepted practice and the recommended level for general ventilation is one complete air change every three (3) minutes. Therefore, a 30,000-cubic foot space requires a general ventilation rate of 10,000 cubic feet per minute.

Natural Dilution Ventilation

The natural means by which confined spaces may be ventilated include wind and thermal convection. These two effects, usually in combination, result from natural pressure differences and air density differences respectively, causing natural displacement and infiltration of air through windows, doors, walls, floors, and other openings. Obviously, if it were sufficient, natural ventilation would be much cheaper than mechanical ventilation, but wind currents and thermal convection are erratic and sometimes hard to predict. Therefore, natural ventilation is unreliable as a primary control method.

Mechanical Dilution Ventilation

In cases where natural ventilation forces are practically nonexistent, mechanical ventilation must be relied on almost completely. Dilution ventilation can be achieved by roof fans used with or without gravity ventilators.

The best method of providing dilution ventilation is to supply air through duct work and distribute it into the work areas in a manner that will provide both humidity and temperature control.

Dilution ventilation is not as effective in contaminant control as is local exhaust ventilation, but it may be required for certain types of operations which cannot be effectively controlled with a local exhaust system. Spray finishing is one such operation. Dilution ventilation requirements may be cal-

culated based on the generation rate of the contaminant, the specified level or percentage of LEL or PEL required to be achieved by dilution, and the applicable PEL or LEL of the contaminant involved.

When attempting to determine whether dilution or local exhaust ventilation is better, it should be remembered that dilution ventilation has four limiting factors:²

1. The quantity of contaminant generated must not be too great or the air volume necessary for dilution will be difficult to provide.
2. Either the workers must be far enough away from contaminant evolution, or the contaminant must be in sufficiently low concentration that workers will not be exposed to concentrations exceeding acceptable levels.
3. The contaminant must have a low toxicity.
4. The evolution or generation of contaminants must be reasonably uniform.

On the basis of these factors, dilution ventilation is usually not recommended for fumes and dust because: (1) the high toxicities often encountered require excessively large quantities of dilution air; and (2) the velocity and rate of evolution are usually very high, resulting in locally high concentrations.

Dilution Ventilation for Comfort

Ventilation for heat relief includes certain aspects of air conditioning or treating of air to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space. In most residential, office, and commercial ventilation, the requirements are comfort for the occupants. In many industrial situations, however, truly comfortable conditions are impractical to maintain; the function of ventilation and air conditioning along with other control methods in these instances is to prevent acute discomfort and adverse physiological effects.

Threshold Limit Values or Acceptable Concentrations for health hazard control are typically one to three orders of magnitude below the lower explosive limit for a given material. A table of comparative values is shown below.³ Exposure to atmospheres controlled to concentrations "below" the lower explosive limit (or some fraction thereof) could cause narcosis, severe illness, or death. Therefore, it is extremely important not to confuse dilution ventilation requirements for health hazard control with fire and explosion prevention.

A local exhaust system captures the contaminants as they are generated, draws them into the duct

Material	TLV		LEL
	ppm	%	ppm
Acetone	1000	2.55	25,500
Ethanol	1000	3.28	32,800
Isopropanol	400	2.02	20,200
Toluene	100	1.27	12,700
Xylene	100	1.00	10,000

work of the system, and removes them from the work environment. Local exhaust systems are most effective in removing contaminants generated at one point, such as welding or localized solvent cleaning.

In contrast to dilution ventilation, local ventilation places much more reliance on mechanical methods of controlling air flow. A local exhaust system usually includes the use of hoods or enclosures, duct work leading to an exhaust fan, an air cleaning device for air pollution abatement, and finally, discharge to the outside air. Local exhaust systems usually contain more mechanical components than general exhaust systems, offer more operational parameters to be controlled within acceptable ranges and therefore require more maintenance.

A local exhaust system is usually superior to dilution ventilation if the main purpose of the ventilation is contaminant control.

If the system is properly designed, for example, the capture and control of a contaminant can be complete. Consequently, the exposure of workers from the sources exhausted can be prevented. With dilution ventilation, the contaminant is diluted when the exposure occurs. In any given confined space, this dilution may be highly variable and therefore unreliable.

The volume rate of required exhaust is less with local ventilation; as a result, the volume of make-up air required is smaller. Local ventilation saves in both capital investment and heating costs.

The contaminant is contained in a smaller exhausted volume of air; therefore, if air pollution control is needed, it is less costly. As a first approximation, the cost of air pollution control is proportional to the volume of air handled.

Many local exhaust systems can be designed to capture large settleable particles or at least to confine them within the hood and thus greatly reduce the labor required for good housekeeping.

Auxiliary equipment in the confined space is better protected from the deleterious effects of the contaminant, such as corrosion and abrasion.

Local exhaust systems usually require a fan of fairly high pressure characteristics to overcome pressure losses in the system. Therefore, the performance of the fan system is not likely to be adversely affected by such factors as wind direction or velocity or inadequate make-up air. Dilution ventilation can be greatly affected by such seasonal factors.

Ventilation System Arrangements

Ventilation systems should be arranged to provide the best possible distribution of air throughout the space and to provide clean, respirable make-up air to replace the contaminated air removed from the space.

Air Circulation

The location of exhaust duct inlets and make-up air inlets is extremely important to achieving proper air distribution throughout a confined workspace. Locating an exhaust fan in the top of a deep, single-opening confined space (where make-up air enters the space through the same opening in which the fan is located) will accomplish very little. Short-circuiting will occur and the fan will exhaust most of the make-up air which enters the space before it can circulate through the space. The distribution of air in this case can be greatly improved by extending a duct from the fan exhaust inlet to the bottom of the space. Air distribution and circulation can be vastly improved when make-up air and exhaust air move through separate openings in the space.

Make-up Air

Make-up air drawn into a space to replace contaminated air must be clean and must contain sufficient oxygen levels for respiration. Make-up air inlets should not be located near exhaust outlets, as this may contaminate the exhaust air being recirculated into the space. Where make-up air and exhaust air move through the same opening, ducting should be provided to carry exhaust air a sufficient distance away from the opening to prevent recirculation of contaminated air.

All local and general exhaust ventilation systems must have air to exhaust and that air supplied pound-for-pound by a make-up air system. The supply and distribution of make-up air is often overlooked or neglected in the design of ventilation. However, it is fundamental to successful operation.

Principles for Supplying Make-up Air

The fresh-air intake should be located away from any contaminating sources such as exhaust stacks or furnace exhausts. The fresh air should be filtered to protect the equipment and to provide maximum heat exchange efficiency.

The air supply system must be provided with a fan; otherwise, the room or building will be under a negative pressure.

Make-up air sources should be located in such a way as to provide cross ventilation. In this way, the air can be used twice. First, it will provide general dilution. Second, it will provide make-up air for the exhaust systems. This does not apply to spot-cooling applications in which the air will be introduced directly at the work station and may vary significantly from room temperature. The air distribution pattern must be engineered carefully to provide effective area coverage without excessive cross drafts that will interfere with the workers or with existing systems.

Make-up air should be introduced into the "living zone" of the work area, that is, below the eight-to-ten-foot level. In this manner, the air is first used by the workers, and maximum results of general or dilution ventilation are obtained. This distribution also provides greater control of the ambient working temperature.

Make-up air is usually heated or cooled to approximately the same temperature as that in the room. Since the air is used for ventilation and replacement purposes, the usual temperature range is between 65 and 80°F.

Exhaust Outlets

Ventilation exhaust outlets containing flammable or toxic substances must be vented to the outside atmosphere in a location that can dilute and disperse the contaminants. Exhaust outlets must not be placed in locations that will allow exhaust air to contaminate adjacent spaces, accumulate or pocket in low areas, or expose workers to harmful or dangerous atmospheres.

Contaminants Lighter or Heavier Than Air

Contaminants lighter or heavier than air will tend to accumulate in the greatest concentrations in the higher or lower areas, respectively, of a confined space. This means that the most dangerous concentrations will be found in these areas. As well, increased temperatures from heated processes or natural causes will increase evaporation and convection rates and cause vapors or gases to diffuse

and rise to the upper portions of the space. Therefore, ventilation arrangements and the placement of exhaust outlets and make-up air inlets should consider these characteristics.

When contaminants heavier than air are present, exhaust outlets should be located near the bottom of the space, with the make-up air inlet at the top of the space. When contaminants are lighter than air, or when temperatures are high, the system should be reversed, with the exhaust outlet at the top of the space and the make-up air inlet at the bottom of the space. These arrangements will allow the ventilation system to capture and remove the contaminants at the point of greatest concentration and with the least amount of dispersal of the contaminants through the space.

Blowing Versus Drawing Air

Air should not be blown into a space which contains flammable or toxic atmospheres. Blowing air into a space will agitate and evaporate the contaminants and disperse them throughout the space. Blowing air into a space will also result in an uncontrolled expulsion of the hazardous atmospheres from the space through any openings in the space. This may result in contamination of adjacent spaces and areas.

Drawing air from the space moves air less effectively, but it produces a controlled capture and removal process. Air may be blown into a space only when no flammable or toxic materials are present or being generated by the work process and only when ventilation is required merely to provide clean, respirable air for breathing and general comfort.

Ventilation Requirements for Specific Operations

It must be emphasized that full effectiveness of ventilation in reducing and maintaining safe levels

of flammable and toxic agents, and providing proper breathing air, can be achieved only through proper sampling of the atmosphere within the space. Compliance with specified minimum ventilation requirements does not in itself ensure that no flammable or toxic hazards will exist, since there are many variables affecting any given work situation. In many cases, it may be necessary to use ventilation in combination with approved respiratory protective devices.

Welding, Cutting, Burning, and Brazing

Whenever possible, local exhaust ventilation must be provided to "capture" contaminants from the source (the point of operation) and remove them from the atmosphere within the confined space. The local exhaust system should maintain an airflow velocity of 100 linear feet per minute in the zone of operation if the exhaust inlet is remote from the point of operation. Capture velocities decrease drastically as the distance between the exhaust inlet and the point of operation increases. Table 12.1 illustrates flow rates with duct sizes and calculated velocities at various distances from the exhaust inlet. These values may be used as guidance when establishing local exhaust systems.

1. Values are based on a minimum duct velocity of 4,000 fpm.
2. Velocity values were calculated from the formulas:

$$V = \frac{Q}{10X^2 + A} \text{ for unflanged openings}$$

$$V = \frac{Q}{.75(10X^2 + A)} \text{ for flanged openings}$$

Where V=velocity in feet per minute

Q=air flow in cubic feet per minute

X=distance from exhaust inlet in feet

A=area of duct in square feet

Table 12.1
EXHAUST VENTILATION FLOW RATES

Distance from Exhaust Inlet	Duct Size (Diameter)	Airflow in Cubic ft/min.	Velocity ft. per min. Unflanged	Velocity ft. per min. Flanged
6"	4"	350	135	180
8"	5"	550	120	163
10"	5"	800	113	150
12"	6"	1200	118	157

Source: NAVSEA S6470-AA-SAF-010

Exposure levels of toxic materials should never be allowed to exceed PEL levels. In cases of hazardous levels, workers must be equipped with NIOSH-approved, respiratory protective devices appropriate for the exposure. Even when respiratory protective devices are used, ventilation is required to capture and remove toxic contaminants from the workspace while avoiding uncontrolled dispersal of toxic materials and possible contamination of adjacent spaces and areas as well as exposure of personnel not directly associated with the operation.

The higher the content of toxic metals or other materials involved in the operation, the greater the airflows required to ensure proper capture of contaminants and provide more dilution. Such materials include, but are not limited to, fluorine compounds, zinc, lead, mercury, beryllium, cadmium, cleaning and degreasing compounds, stainless steels involving chemical flux, iron powder, gas shielded arc, or halogenated hydrocarbons.

Where local exhaust ventilation is impractical, due to the location, configuration, or nature of the space or to similar restrictive factors, dilution ventilation or portable collectors must be provided. However, it must be recognized that dilution ventilation is seldom applied successfully to fume and dust control operations, due to uneven rates of contaminant evolution, lack of accurate data of amount of contaminant generated, high volumes of dilution air required, etc. Poor air circulation and distribution, with workers immediately adjacent to the point of operation where contaminants are at their highest level of concentration, further compound the problem. Workers must be equipped with NIOSH-approved respiratory protective devices appropriate for such exposure. Dilution ventilation provides a means of diluting, collecting, and removing contaminated air from the space in a controlled manner. Adjacent areas and spaces must not be contaminated by the exhaust. Exhaust discharges must be filtered to remove the contaminant or located in an area which will permit rapid dispersal in the outside atmosphere as appropriate.

Requirements of 29 CFR (Code of Federal Regulations) 1910, 29 CFR 1915, and the American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation Manual state:

One air change every three minutes, but not less than 2,000 cfm per welder where 5/32" or 3/16" rod is used, 3,500 cfm per welder where 1/4" rod is used, or 4,500 cfm per welder where 3/8" rod is used. Dilution airflows must be shown

by test and evaluation to be adequate to maintain concentrations of contaminants in the workers' breathing zones at or below permissible exposure levels (PELs). Otherwise, workers must be equipped with NIOSH-approved respiratory protective devices.

Painting, Coating, and the Use of Solvents

Paint and preservative coating removers, cleaning solvents, liquid vehicles for paints and preservative coatings, and similar materials are frequently toxic and flammable. Because contaminants generated from these types of operations are dispersed over a wide area rather than at a single point of generation, local exhaust ventilation is not effective in controlling contaminants. Dilution ventilation is the only type of ventilation that will be effective here.

Dilution to Personnel Exposure Limits

To control toxic exposures, ventilation must dilute contaminants to 25% or less of their established PELs. Due to the nature of the ventilation problems in confined spaces described above, workers must be equipped with NIOSH-approved respiratory protective devices except where sampling tests establish that concentrations of contaminants are maintained within acceptable PELs.

Dilution to Lower Explosive Limit

Certain operations may generate contaminants in excess of PEL and LEL levels. Workers must not occupy the affected spaces during periods when concentrations exceed 10% of the LEL or when toxic concentrations are immediately dangerous to life or health (IDLH).

Where sufficient airflows cannot be provided to dilute contaminants to established PELs, ventilation must be provided to dilute contaminants to 10% or less of the lower explosive limit of the material involved and workers must be equipped with appropriate NIOSH-approved respiratory protective equipment. Ventilation must be continuous during and after operations until flammable materials have evaporated and the space is gas free.

Final testing of the space should be conducted after the ventilation system has been secured for at least ten minutes. Frequent testing of the space must be conducted during operations to ensure that flammable atmospheres do not develop. When concentrations of flammable vapors exceed 10% of the LEL, operations must be stopped and workers evacuated from the space. Operations cannot be resumed until ventilation is performing correctly.

However, it must be remembered that operations

such as spray painting will produce flammable concentrations within the cone-shaped space at the spray nozzle. These flammable concentrations within the spray cone usually will not be cause to discontinue operations unless they are sufficient to affect the total atmosphere within the space. Where flammable concentrations are found to exist at significant distances outside the spray cone, the dilution ventilation system must be considered suspect and the actions described above taken.

Abrasive Blasting

Contaminants produced by abrasive blasting in confined or enclosed spaces cannot reasonably be controlled by ventilation. Workers performing such operations must always be equipped with NIOSH-approved respiratory protective devices and other personal protective equipment as required. Ventilation must be provided, but it can be expected only to remove suspended dust particles from the atmosphere and thereby increase the visibility within the space. Air velocity in exhaust ducts should provide adequate transport of dust particles. Exhaust air should be filtered or otherwise processed to remove contaminants as may be required by state and/or federal environmental protection requirements.

Notes

1. Adapted from *The Industrial Environment—Its Evaluation and Control* (Washington, D.C.: National Institute for Occupational Safety and Health, 1973), Chapter 39, "Principles of Ventilation," by John E. Mutchler.
2. *Industrial Ventilation—A Manual of Recommended Practice* (Lansing, Michigan: American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation, 12th Ed., 1972). Adapted slightly.
3. Compiled from figures by the American Conference of Governmental Industrial Hygienists.
4. Adapted from John E. Mutchler, *op. cit.*

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1. American National Standard Institute (ANSI) Z117.1—1977.
2. *Gas Free Engineering*, NAVSEA S9086-CH-STM-030.
3. *Gas Free Engineering Program*, NAVSEA S6470-AA-SAF-010.
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5. Morse, George L. and Swift, Richard L., "Working Safely in Confined Spaces," *Plant Engineering*, April 29, 1982.

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Instruction Key—Unit 12

Cleaning and Ventilating Confined Workspaces

Terms

1. Natural ventilation—a method of air movement that relies on normal air currents
2. Mechanical ventilation—a method of air movement that uses equipment to increase the motion of the air

Points for Discussion

1. Potential hazards
 - a. workers unfamiliar with necessary safety precautions
 - b. safety measures not correctly followed
2. Preliminary preparation
 - a. worker education
 - b. supervisor's background knowledge
 - c. survey of mechanical equipment and surrounding area
3. Cleaning methods
 - a. removal of material and isolation of the tank
 - b. steam cleaning
 - c. hot or cold water washing
 - d. cleaning small tanks
 - e. chemical cleaning
 - f. special precautions for cleaning tanks without ventilation
 - g. special precautions for tanks containing leaded gasoline
4. Specific problems which may be encountered
 - a. water-soluble flammable liquids
 - b. acids and alkalis
 - c. non-flammable hydrocarbons
 - d. chemicals containing enough oxygen to support combustion in an otherwise inert atmosphere
 - e. reactive or unstable materials
 - f. paint and varnish tanks
 - g. non-toxic, nonflammable materials
5. Properties of airborne materials
 - a. dusts
 - b. fumes
 - c. mists
 - d. smoke
 - e. vapors
 - f. gases
6. Ventilation
 - a. natural ventilation
 - b. mechanical ventilation
 - c. steam ventilation

7. Classification of ventilating systems
 - a. dilution ventilation
 - b. local exhaust ventilation
8. Ventilation system arrangements
 - a. air circulation
 - b. make-up air
 - c. principles for supplying make-up air
 - d. exhaust outlets
 - e. contaminants lighter or heavier than air
 - f. blowing versus drawing air
9. Ventilation requirements for specific operations
 - a. welding, cutting, burning and brazing
 - b. painting, coating and the use of solvents
 - c. abrasive blasting

Questions

1. Of the two ventilation methods, dilution ventilation and local exhaust ventilation, which is generally preferred? Why?
2. When making arrangements for the placement of exhaust outlets and make-up air inlets, why is it important to know the weight of the contaminant in relation to the weight of air?
3. Comment briefly on the following statement: "Because blowing air into the confined space is the most effective means of moving air, it is the best way to ventilate the space."
4. What are the three major methods of cleaning confined spaces?

Answers

1. Local exhaust ventilation is generally regarded as superior because it removes the contaminant at its source. Dilution of the contaminant may be too variable to be reliable.
2. Contaminants that are lighter than air will form their most hazardous concentrations in the upper-most portions of the confined space. In this case, exhaust outlets should be located near the top of the space with the make-up air inlet at the bottom. Contaminants that are heavier than air will form their most hazardous concentrations in the bottom portions of the confined space, so ventilation arrangements must be just the reverse: with the exhaust outlet at the bottom and the make-up air inlet at the top.

3. The statement is only half true. Blowing air is indeed the most effective way of moving air, but it will only agitate and evaporate the contaminants, dispersing them throughout the space. It may also scatter the contaminants to areas outside the space. While drawing air is a less effective means of moving air, it provides more control over the removal of the contaminant and is therefore generally the preferred method of moving air.
4. The three major methods are steam cleaning, hot or cold water washing, and chemical cleaning.

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UNIT 13

HOT WORK

For the purpose of this unit, hot work includes all flame heating, welding, torch cutting, brazing, carbon arc gouging, or any work which produces heat, by any means, of 400°F (204.4°C) or more; or in the presence of flammables or flammable atmospheres, other ignition sources such as spark or arc-producing tools or equipment, static discharges, friction, impact, open flames or embers, non-explosion-proof lights, and so forth.

SAFETY AND HEALTH HAZARDS

Fumes and Dusts

The fumes from welding, brazing, and thermal cutting are visibly apparent in these processes. A *fume* is formed from particles generated when the material from a volatilized solid condenses in cool air. Fumes are generated whenever the heat applied to effect a process is sufficient to raise the temperature of a substance high enough to cause vaporization. These temperatures may range from about 450°C for brazing to well above 16,000°C for plasma arc cutting. Substances that become fumes may originate from the base metal being worked on, from coatings previously applied to the base metal, from the flux present, or from the filler metal being used.

Besides fumes, other solid materials may become airborne in hot work operations. Fluxes and filler material used in a powdered form, as in submerged arc welding and furnace brazing, may enter the air as fugitive dusts.

The generation rate of fumes normally increases with increasing current level.

Effects of Exposure

The nature of hot work requires the application of intense energy to change the physical state of metals. This application of intense energy makes these operations potentially hazardous. As the energy is applied, a number of hazardous physical agents may be generated, including noise, vibration,

heat, electrical current, and the various types of ionizing and non-ionizing radiation. The chemical changes associated with the interaction of such energy with materials present in the process may result in emission of various toxic fumes, dusts, gases, and vapors. The situation is worsened by the fact that most of the processes require close involvement of workers to regulate the actual hot work processes.

The degree of health risk posed by hot work varies with the method employed, work practices used, metals and fluxes involved, control measures employed, and duration of exposures.

Health effects associated with hot work fall into the following categories: respiratory, gastrointestinal, ocular, dermal, auditory, and muscular.

Respiratory

Metal fume fever is an acute industrial disease of short duration caused by the inhalation of metal oxide fumes, usually freshly generated. Zinc oxide has been the most common cause of the fever among welders. The effects of metal fume fever simulate symptoms of upper respiratory infection, influenza, acute bronchitis, or pneumonia, and are characterized by chills, shivering, trembling, nausea, vomiting, and other forms of gastrointestinal disturbance. The attack usually lasts from six to twelve hours. In some instances, it may last up to twenty-four hours.

Metal fume fever often occurs in manual electric arc welding where mixed fumes are generated. The fumes may contain iron, calcium, fluoride, manganese, silica, titanium, aluminum, copper, and nickel. In some instances, traces of potassium, sodium, chromium, molybdenum, tin, lead, and magnesium are also found.

Fibrosis, respiratory impairment. Bare-wire electrodes have been replaced to a large extent with coated electrodes. Besides iron, these coatings often include silicon, silicates, fluorides, titanium, manganese, copper, and other metals. With the

increased use of coated electrodes, there have also been increases in reports of fibrosis, respiratory impairment, and lesions in the lungs.

Phosgene exposure. Phosgene may be responsible for respiratory distress among welders in confined workspaces, due to the use of certain refrigerants and solvents and to inadequate ventilation. Cases of phosgene poisoning have been recorded among welders performing arc welding on steel which was being cleaned with trichloroethylene.

Gastrointestinal

Gastrointestinal disturbance is common in welders experiencing metal fume fever. The effects of this disturbance are usually in the form of nausea, vomiting, and gastrointestinal obstruction.

Ocular

Welders without proper eye protection for their eyes may suffer retinitis caused by welding light or arcs. The effects of this exposure may produce blurred vision, cataracts, retinal injury, and other eye abnormalities. Eye injuries are also caused by metal splatter from hot slag, metal chips, sparks, and hot electrodes. Some eye injuries are caused by flying debris entering workers' eyes when workers remove their goggles to adjust them.

Dermal

Dermal effects related to hot work may result from exposure to ultraviolet (UV) radiation, from sensitization metals, and from hot metal splatter. The most common sites for such burns are the arms, hands, neck, and chin. Without adequate protection when arc welding, welders may develop chronic dermatosis of the face, neck, eyelids, scalp, hands, forearms, back, and lower extremities caused by welding-torch radiation.

Auditory

Hearing loss among welders has usually been due to traumatic injury or to sound pressure. Welders without adequate protection may have their eardrums perforated by flying sparks or pieces of metal during welding and thermal cutting operations. Such an injury nearly always results in permanent hearing loss.

Auditory impairment from exposure to potentially hazardous noise levels may occur during butt welding, metal spraying, and plasma jet processes. Research indicates that workers face a considerable risk of noise-induced deafness while performing arc-air gouging without adequate ear protection.

Fire Hazards

Fires

The fire hazards caused by welding, due either to the direct flame or to the flying sparks, are responsible for injuries that can sometimes be fatal among welders. Fires associated with oxygen-enriched atmospheres are good examples of the risks involved when there is either accidental enrichment of the air by oxygen in confined workspaces or intentional enrichment for some purpose.

Intentional oxygen enrichment or "sweetening" of the air in an attempt by a worker to purge contaminants from a confined workspace has been, in several instances, the cause of severe injuries and fatalities. In one situation, a welder enriched the inside atmosphere of a storage tank with oxygen from a cylinder outside the tank and then proceeded to enter the tank to make repairs by electric arc welding. While inside the tank, the welder's clothing suddenly ignited. The welder was burned extensively and died on the way to the hospital.

In a second situation, a welder was descending a deep well to cut a rusty suction basket from a pump. Before he descended, he fed oxygen, instead of compressed air, down into the well because he thought there might be dangerous gases. When he started to cut, his clothing burst into flames and he fell into the water. Rescue attempts were delayed and the welder was dead when he was removed from the well.

In situations where atmospheres in a confined workspace contain oil mist, fine particles of dust, or explosive gases and vapors (such as methane), welding poses a serious threat to the workers.

Fire Control

A combination of engineering controls and the use of personal protective equipment will help to reduce the hazards associated with hot work.

Space Cleaning and Ventilating

Before beginning hot work in a confined workspace, the space must be tested, inspected, cleaned, ventilated, and an entry permit issued as specified by other units in this manual. Extraneous flammable or combustible materials, such as scrap wood, paper, rope, rags, etc., should be removed from the space. Combustible materials which cannot be removed should be adequately protected and ventilation provided.

Boundary Spaces

Spaces adjacent to the space in which hot work

is to be performed (above, below, and on any of the sides), should also be inspected and tested, cleaned, and ventilated or inerted as appropriate.

Fire Prevention

When open flame or heat-producing work such as welding, cutting, brazing, etc., is to be conducted in the presence of combustible materials or flammable residues, a fire watch trained in the nature of any fires which might occur and in the proper use of the fire extinguishing equipment provided should be established. Where hot work may create temperature increases in a wall, bulkhead, or other separating structure which may create fire hazards on the opposite side of the structure, a fire brigade should also be established on the opposite side to alert workers to hazardous conditions.

Fire Extinguishing Equipment

Suitable fire extinguishing equipment must be provided based on the nature and extent of the flammables or combustibles present and the fires which may be expected to occur. Vaporizing liquid extinguishers should never be used in confined or enclosed spaces. Carbon dioxide extinguishers should be used only after careful evaluation of the exposure and determination that discharge of carbon dioxide into the space is not likely to cause a hazard to workers. Water extinguishers or water hoses equipped with fog nozzles or fog applicators are most suitable for hot work in the presence of ordinary (Class A) combustible materials or flammable residues or coatings.

See Unit 14, "Fire Hazards and Fire Protection," for full coverage of all fire hazards in confined workspaces and detailed precautionary measures.

Other Hazards

Electrical Shocks

Because current intensities of 100-600 amps and 30-60 volts, either AC or DC, are used in welding, shocks are always a possibility. Electrical shock has resulted in a variety of accident and injury types, leading to serious injuries and deaths. The usual practice in arc welding operations is to have the work connected to one pole of the current and the electrode to the other. Fatalities have resulted from current passing through the body when a welder stepped on the "live" electrode while in contact with the other pole of the current. Careless handling or changing of electrodes has also been responsible for fatalities.

In one instance, an electric arc welder was working in a confined workspace where the temperature was 35°-40°C (95°-104°F). He had perspired heavily and had removed one glove. The welder developed spasms and burnlike lesions on his lower buttock, left thigh, and left hand, apparently from electrical contact. He died shortly after.

See the appendix that follows this unit for specific hazards of metals, gases, and other agents common to hot work.

HOT WORK IN THE PRESENCE OF PRESERVATIVE COATINGS

Flammable Coatings

The flammable nature of coatings should be determined before hot work is begun in a confined space. Where the flammability of the coating is unknown, tests should be conducted. Combustible coatings must be removed from the location of the hot work for a distance sufficient to prevent ignition or outgassing (from temperature increase) of coating materials in the unstripped areas. The distance required for stripping of coating materials will vary according to the material involved and the nature of the hot work, but in no case should it ever be less than four inches on all sides from the outermost limits of the hot work. Periodic or continuous monitoring must be conducted while the hot work is performed to ensure that flammable atmospheres are not being produced. Where significant outgassing is detected, hot work must be stopped and further stripping conducted, artificial cooling methods employed, or other means applied to prevent temperature increases in the unstripped areas. Flame or uncontrolled heat cannot be used for stripping flammable coatings. Hot slag or sparks should be prevented from falling onto flammable coatings in the area of the hot work. Surrounding areas may also be wetted down to reduce ignition potential. Ventilation should be provided in accordance with procedures described in Unit 12.

Toxic Coatings

Coatings which may release toxic vapors upon the application of heat should also be stripped from the area of the hot work for a distance sufficient to prevent temperature increases in the unstripped surfaces which would result in toxic vapor or fume release. In the absence of sufficient stripping to prevent toxic vapor or fume release, workers should wear approved respiratory protection and ventilation should be provided.

Soft, Greasy Preservative Coatings

Soft, greasy coatings may present hazards more serious than those presented by hard surface coatings. Some soft coatings may have much lower flash points, emit gases at lower temperatures, and ignite more easily from hot slag or sparks. These problems are often further complicated by difficulty in walking, standing, and maneuvering on very slippery surface, increasing the possibility of falls, dropping lighted torches on unstripped materials, etc. Therefore, before hot work is performed in a confined or enclosed space coated with soft, greasy preservatives, such materials must be stripped, cleaned, or otherwise removed from the area of hot work for a distance sufficient to prevent outgassing and to prevent ignition from heat, sparks, slag, etc.

HOT WORK IN THE PRESENCE OF SCALING

Blisters, scales, and similar conditions inside tanks that have held flammable materials may, even after cleaning and ventilating, retain residues of flammable materials. Hot work in the presence of such conditions must be carefully evaluated to determine the proper procedures and control measures for the operation. The following factors must be considered:

1. The material last contained in the tank and previous cargoes that may alter the characteristics of existing residues;
2. The flash point and auto-ignition temperature of any residues. Tests must be conducted, where necessary, to determine this information;
3. The extent (depth, porosity, percent of surface covered, etc.) of scaling and blistering;
4. The possibility of a surface flash that would involve the entire space.

Scale containing highly flammable residues (with a flash point of 100°F or less such as gasoline), should be completely cleaned and removed from the space prior to the commencement of hot work. Scale or blisters containing residues of less flammable materials (with a flash point above 100°F such as fuel oil), should be cleaned away from the area of the hot work for a distance sufficient to prevent temperature increase in the uncleaned areas to a level that would produce flammable vapors. The area cleaned must be at least four inches away on all sides from the outermost limit of the hot work. In all cases, the area cleaned must be sufficient to prevent outgassing from surrounding areas and to prevent ignition of residues. Areas below the hot work should be either cleaned or protected by

screens, devices which will capture sparks and slag, or similar measures. Water wet-down of areas around the area of hot work will help to reduce the vaporization of residues and reduce the possibility of small fires and flashes.

PIPES, TUBES, AND COILS

Pipes, tubes, or similar items which service or enter and exit a confined workspace should be flushed, blown, purged, or otherwise cleaned before the performance of hot work on such items. Where such items are not so treated, they should be prominently tagged "Not Safe for Hot Work." Valves to pipes, tubes, or similar items should be closed and the pipes blanked off to prevent inadvertent discharge or backflow of materials into the space.

HOT WORK IN THE PRESENCE OF PRESSURIZED SYSTEMS

Before hot work begins in areas that contain pressurized systems (such as hydraulic systems, refrigerant systems, etc.), the systems should be depressurized if they could be affected by the hot work. Piping, fittings, valves, and other system components should be protected from damage resulting from contact with flames, arcs, hot slag, or sparks. All contamination within the space, such as leaking hydraulic fluids, should be cleaned and removed before hot work is begun. Hydraulic fluids in the presence of high temperatures can decompose and produce highly toxic by-products.

GAS WELDING, CUTTING, AND BRAZING

Compressed Gas Cylinders

Compressed gas cylinders are to be transported, handled, and stored in accordance with the provisions of construction safety and health standards. Compressed gas cylinders or gas manifolds used in welding and cutting operations should never be taken into a confined space. Instead, the cylinders or manifolds should be placed outside the space, in open air, in an area not subjected to any fire, explosion, or emergency that may occur within the space.

Cylinders with a capacity of over thirty pounds should have a valve protection cap. These caps should be kept in place at all times.

Gas Welding and Cutting Equipment

Gas welding and cutting equipment, such as hoses, connections, torches, etc., must be inspected, tested, operated, and maintained in accordance with the appropriate standards. In addition, hoses should be turned off at the source and rolled up when not in use.

Gas Supplies

Gas supplies should be turned off at the cylinder or manifold outside the space when equipment is unattended or unused for substantial periods of time, such as at breaks or lunch periods. Gas supplies must be immediately removed from the space when torches or other devices are removed from the hose.

ELECTRIC ARC PROCESSES

Electric Arc Units or Machines

Electric arc units or machines must not be taken into a confined or enclosed space. Such units should be placed outside the space.

Electric Arc Equipment

Electric arc equipment should be inspected, tested, operated, and maintained in accordance with the provisions of 29 CFR 1910, 29 CFR 1915, or 29 CFR 1926, as appropriate.

Electrode Holders

When electrode holders will be left unattended or unused for a period of time such as at breaks or lunch periods, the electrodes should be removed from the holders, the holders placed in a safe location or protected, and the power switch to the equipment opened. If unattended for extended periods of time, such as overnight, electrode holders, cables, and other equipment should be removed from the space and the power supply to the equipment disconnected.

Inert Gas Processes

When processes are used that incorporate the use of inert gases, care should be taken to ensure that the confined or enclosed space does not become oxygen deficient. Adequate ventilation should be provided to remove inert gases discharged into the space during the operations and to maintain required oxygen levels. Hoses, connections, and fittings should be inspected to ensure that no leaks are present. Inert compressed gas sources should

be located outside the space and turned off at the source when equipment is unused or unattended. If unattended for extended periods of time, such as overnight, the equipment should be removed from the space or completely disconnected and the gas supply turned off at the source.

Hazardous By-Products

Welding, cutting, or burning in the presence of certain materials (such as hydraulic fluids, refrigerants, chlorinated solvents, halons, etc.) or the application of heat to such materials can result in the decomposition of the materials and the production of hazardous by-products. Hot work should never be conducted on, or in the vicinity of, such materials. Welding or cutting operations which produce high levels of ultraviolet radiation should not be conducted within 200 feet of exposed chlorinated solvents.

PURGING SYSTEMS FOR WELDING OPERATIONS

When using argon, nitrogen, or any inert gas to purge a system or line, a responsible person should tag out all outlets throughout the entire line regardless of the area through which the line penetrates. The tag will identify the superintendent's name, date of purge, and phone extension number. Those responsible for performing the purge will be responsible as well for assuring that the system is substantially sealed to prevent leakage to any unknown area. The purge will be vented in an outside area where there are no confined workspaces nor the possibility of accumulation. When the purge is taken off, the tags shall be removed by the person or persons designated by the supervisor who initiated the purge.

References

1. Information in the section on chemical and physical hazards was adapted from a NIOSH study on health hazards associated with welding, 1982.
2. NAVSEA Training Manual No. S6470-AA-SAF-010.

Instruction Key—Unit 13

Hot Work

Terms

1. Fume: a substance formed from particles generated when the material from a volatilized solid condenses in cool air.
2. Metal fume fever: an acute industrial disease caused by the inhalation of metal oxide fumes and characterized by chills, trembling, nausea, vomiting, and other forms of gastrointestinal disturbance.

Points for Discussion

1. Safety and health hazards
 - a. Fumes and dusts
 - b. Respiratory effects: metal fume fever, fibrosis, respiratory impairment, phosphine exposure
 - c. Ocular effects
 - d. Dermal effects
 - e. Auditory effects
 - f. Muscular effects
2. Fire hazards
3. Fire control
 - a. Space cleaning and ventilating
 - b. Boundary spaces
 - c. Fire prevention
 - d. Fire extinguishing equipment
4. Electrical shock
5. Other hazards
 - a. Hot work in the presence of preservative coatings
 - 1) flammable coatings
 - 2) toxic coatings
 - 3) soft, greasy preservative coatings
 - b. Hot work in the presence of scaling
 - c. Pipes, tubes, and coils
 - d. Hot work in the presence of pressurized systems
 - e. Gas welding, cutting, and brazing
 - 1) compressed gas cylinders
 - 2) gas welding and cutting equipment
 - 3) gas supplies

- f. Electric arc processes
 - 1) electric arc units or machines
 - 2) electric arc equipment
 - 3) electrode holders
 - g. Inert gas processes
 - h. Hazardous by-products
 - i. Hot work on closed containers or structures
6. Purging systems for welding operations

Questions

1. What is the most common cause of metal fume fever among welders?
2. What major systems of the body may be affected by exposure to welding operations?
3. What are some ways of controlling the fire hazard in a confined space?
4. Which is more hazardous: hard surface coatings or soft, greasy coatings? Explain your answer.

Answers

1. Zinc oxide is the most common cause.
2. Exposure to welding operations may cause respiratory, gastrointestinal, ocular, dermal, auditory, and muscular damage.
3. The space should be cleaned and ventilated. Adjacent spaces should also be inspected and protected if necessary. A fire brigade should be trained and established nearby. An effective communication system will help the fire brigade to work more efficiently. And the proper fire extinguishing equipment should be provided for the specific hazards.
4. Soft, greasy coatings may be more hazardous than hard coatings. Soft coatings may have much lower flash points, may emit gases at lower temperatures, or may ignite more easily from flying sparks. As well, these coatings produce very slippery surfaces, increasing the possibility of falls.

Appendix
SPECIFIC HAZARDS OF HOT WORK OPERATIONS

Adapted from a NIOSH study on health hazards
associated with welding, 1982

SPECIFIC HAZARDS OF HOT WORK OPERATIONS

Agent	Toxic Effects
METALS	
Aluminum	pneumoconiosis, necrosis of the cornea
Aluminum salts	irritation of upper respiratory tract, dermatosis, eczema, conjunctivitis
Arsenic	sensitization, perforation of nasal septum, electrocardiogram changes, cirrhosis of the liver, cancer (lung, lymphatic, skin), hyperpigmentation, palmer and plantar warts, hyperkeratosis, contact dermatitis, conjunctivitis
Beryllium	acute pneumonitis, bronchogenic cancer, chronic pulmonary granulomatosis, dermatitis, ulcers, ocular disorders
Cadmium	pulmonary edema, anemia, kidney malfunction, emphysema, nasal ulceration and irritation, possibly prostate cancer
Chromium	perforation of nasal septum, kidney and liver damage, pulmonary congestion, edema, epigastric pain, erosion and discoloration of teeth, perforated eardrums, lung cancer, contact dermatitis, skin ulcers
Cobalt	pulmonary fibrosis, respiratory sensitization (asthma), dermatitis, polycythemia and hypothyroidism (animals)
Copper	upper respiratory tract irritation, metallic taste in mouth, nausea, metal fume fever, ulceration and perforation of nasal septum
Iron	siderosis, lung cancer
Lead	anemia, nausea, constipation, colic, wrist drop, palsy, seizures, coma, behavioral disorders, changes in kidney function, teratogen (rats and mice)
Magnesium	irritant of nasal mucosa and conjunctiva, metal fume fever, digestive disorders
Manganese	eye irritation, respiratory tract mucous membrane, loss of appetite, headache, spasms, euphoria, mental confusion, speech disturbance, disturbance in gait and balance, chronic neurologic disorders
Molybdenum	irritation of mucous membrane, irritation
Nickel	cancer (nasal, lung, laryngeal, kidney)
Silver	argyria, pigmentation of skin and eyes, pneumoconiosis
Tin	stannosis
Titanium	pulmonary fibrosis, acute bronchitis, upper respiratory injury
Tungsten	pulmonary fibrosis, loss of appetite, nausea, coughing, eczema, pruritis

SPECIFIC HAZARDS OF HOT WORK OPERATIONS

Agent	Toxic Effects
Vanadium	respiratory tract irritation, bronchitis, chest pain, cough, nausea, diarrhea, discoloration of the tongue, contact dermatitis, skin irritation, conjunctivitis
Zinc	zinc fume fever, dermal sensitization, corrosive to skin and mucous membrane
GASES	
Ozone	headache, chest pain, cough, fatigue, dryness of upper respiratory tract, irritation of mucous membrane, pulmonary irritation and edema, lower blood pressure
Oxides of Nitrogen	irritation of the eyes and mucous membranes, cough, headache, pulmonary edema, chronic pulmonary impairment, emphysema, methemoglobinemia, pulmonary dysfunction with decreased vital capacity
Carbon Dioxide	CNS effects, respiratory stimulation, unconsciousness, convulsions, headache, sweating, dizziness, mental confusion, faintness, restlessness, respiratory acidosis, and pulmonary insufficiency
Carbon Monoxide	nausea, vomiting, dizziness, drowsiness, collapse, and myocardial changes, carboxyhemoglobin formation, pulmonary edema
Phosgene	residual pulmonary effects, pulmonary edema
Acetylene	anesthetic effect, pulmonary edema, bronchospasm, urticaria
OTHER AGENTS	
Fluorides	increased bone density, osteosclerosis, nausea, vomiting, diarrhea, pulmonary edema
Silica	silicosis, decrease in pulmonary function
Visible Radiation (400-760 nm)	retina changes (scotoma), ocular discomfort, eye fatigue, headache
Ultraviolet Radiation (200-400 nm)	photokeratitis, erythema dermatitis, skin cancer, burns, conjunctivitis, keratitis, cataracts (possibly)
Ionizing Radiation	erythema, radiodermatitis, nausea, vomiting, diarrhea, weakness, shock, cancer, cataracts, reproductive disorders
Noise	hearing loss, cardiovascular disorders, endocrine deficits, neurologic changes
Vibration	localized stress injury to fingers and hands (Raynaud's phenomenon)
Thermal Energy	irritability, lassitude, anxiety, decrease in morale, inability to concentrate, heat rash, heat cramps, heat exhaustion, heat stroke, burns
Electrical Energy	electrocution, burns, explosions

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UNIT 14

FIRE AND FIRE PROTECTION

Fire protection is another vital factor in the total confined workspace safety and health program.

Fundamentals of Fire

Fire is the result of oxygen and fuel combining in the proper temperature range to sustain combustion. Combustion is the chemical process in which, as a result of applied heat, fuel and oxygen unite at a rapid rate, producing light and heat.

The Fire Pyramid

There are four elements in the classic fire pyramid model: fuel, oxygen, heat, and an uninhibited chain reaction.

Fuel is usually in abundant supply from such sources as gasoline, paint, solvents, plastics, oily rags, hydrogen generated during battery charging, cleaning materials, sawdust, paper, and scrap. Common chemical elements also serve as fuels. These include carbon, hydrogen, and sulfur.

The *oxygen* necessary for a fire is in plentiful supply from the open air itself. Normal breathing air generally contains about twenty-one percent oxygen. The construction setting also often contains oxidizing agents which support combustion. Such agents include hydrochloric and nitric acids and nitrogen oxides.

Fuel will not burn, nor the union of oxygen and fuel take place, until a certain temperature is reached. Various fuels will ignite at various temperatures.

Heat may be produced by friction, an electric spark, chemical action, the rays of the sun, or heat from other burning materials. In the construction setting, the source of ignition may also come in such forms as open flames, sparks, heating systems, welding, hot metal, and electrical equipment.

The *uninhibited chain reaction* means, quite simply, that the fire will progress if nothing is done to impede its progress. But what do we mean when we say "to impede the fire's progress"?

Removing One Side of the Fire Pyramid

The most common way of preventing fires is by eliminating either the fuel or the heat (source of ignition). To extinguish a fire, it is necessary to remove one side of the pyramid.

1. *Fuel*—Remove or seal off fuel by mechanical means, or divert or shut off the flow of burning liquids or gases.
2. *Oxygen*—Exclude the air by smothering or by dilution.
3. *Heat*—Cool the burning material below its ignition point with a suitable cooling agent.
4. *Chain reaction*—Interrupt the chemical chain reaction of the fire by using chemical or Halon extinguishing agents.¹

Later in this unit, we will discuss extinguishing methods more fully.

Heat Transfer

Heat may be transferred in a number of ways. The most common means of fire spread or fire propagation is the direct contact of flammable or combustible materials with a flame.

Conduction is the transfer of heat from one body or object to another through an intervening conducting medium, usually a solid.

Convection is heat transmission by a circulating medium, either gaseous or liquid. Since heated media expand and rise, the hot gases and smoke convey heat and toxic gases to the upper floors. The more intense the fire, the greater the speed with which the smoke and heat rise. Convection of smoke, heat, and toxic gases through vertical openings presents grave dangers to persons on the upper floors of buildings. Some toxic gases from fire are carbon monoxide (CO), sulfur dioxide (SO₂), and heated air.

Heat waves or rays given off by a heated body travel in all directions in straight lines until they are absorbed or reflected by another object. The amount of heat radiated from the source increases very rapidly as the temperature of the source rises.

The amount of radiant heat reaching an exposed object depends upon the temperature difference between the heat source and the object and upon the distance between them.

Explosions of flammable dust usually occur in a series, with the later explosions causing the most serious damage. Fire, which may or may not cause another explosion, occurs after the initial explosion.

Sources of Ignition

The origins of most fires can be traced to twelve general causes (plus a small category labelled merely "miscellaneous").

Electrical failures and misuse of electrical equipment are the principal causes of fires. Some specific causes of such fires are electrical arcing, short circuits, overloaded circuits and equipment, and sub-standard wiring. Proper maintenance and periodic inspection of electrical equipment and proper job training will reduce the hazards of this ignition source. Haphazard wiring, poor connections, and "temporary" repairs must be brought up to standard. Fuses should be of the proper type and size. Circuit breakers should be checked to see that they have not been blocked in the closed position, which results in overloading, and to see that moving parts do not stick. The National Electrical Code, NFPA Standard No. 70, should be used as guideline.

Smoking and matches are the second most common cause of fire. This potential ignition source can be controlled if workers will follow smoking regulations and will smoke only in nonhazardous, permitted areas.

Fires caused by *friction* usually result from hot bearings, misaligned or broken machine parts, or choking or jamming of materials in the machinery. Friction can be eliminated by proper maintenance and lubrication and regular inspection of all mechanical equipment.

Another cause of fire is *overheated materials*. These result most commonly from hot work operations.

Control of such fires requires:

1. Proper clearances of combustible materials around the hot work area.
2. Adequate insulation and air circulation between hot surfaces and combustibles.
3. Proper job training and careful supervision.

Fires caused by *burner flames* are usually the result of improper use or poor maintenance of portable torches, boilers, dryers, and portable heating equipment. The sources of fires started by sparks can usually be traced to burning rubbish, engine

stocks, foundry cupolas, furnaces, and welding stations.

Spontaneous ignition occurs when combustibles and oxygen in the air are heated sufficiently to begin a reaction which continues until the combustible material reaches a temperature at which the reaction becomes self-sustaining. This temperature level is known as the ignition point or ignition temperature. Spontaneous ignition is usually the result of improper disposal of oily waste and rubbish and of deposits in ducts and flues.

Fires that occur as the result of *cutting and welding operations* are usually caused by sparks and hot metal landing near welding surfaces, or by defective gauges or deteriorated gas lines on the welding apparatus. Proper training of workers in the recognition of hazards during cutting and welding will help reduce these ignition sources.

Fires that occur through *exposure* are usually caused by heat from adjoining or nearby buildings.

Incendiary fires are started on purpose and with malicious intent by workers or by intruders.

Fires caused by *mechanical sparks* are usually generated by metal in machines or during grinding and crushing operations. Proper care in cleaning and keeping stock free of foreign metallic pieces will prevent sparks from causing fires.

Chemical fires start when chemicals react with other chemicals or materials or when decomposition causes chemicals to be unstable. The best preventives are proper operation and careful handling and storage, particularly avoiding conditions of heat and shock.

Fires from *static* are the result of contact and separation of materials that ignite flammable vapors, dusts, and fibers. These static charges are generated on agitation and mixing equipment, belts, splash-filling of tanks, etc. They can be prevented by grounding, bonding, ionization, and humidification.

Static Electricity²

Static electricity is generated by the contact and separation of dissimilar materials. For example, static electricity is generated when a fluid flows through a pipe or from an orifice into a tank.

The principal hazards created by static electricity are those of fire and explosion, which are caused by spark discharges containing sufficient energy to ignite any flammable or explosive vapors, gases, or dusts which are present. Workers may also be subjected to shock, causing an involuntary reaction (such as falling), which may lead to injury.

Static sparks are most dangerous where flammable vapors are present in the air, such as at the outlet of a flammable liquid fill pipe, a delivery hose nozzle, near an open flammable liquid container, and around a tank truck fill opening or barrel bung hole. A spark between two bodies occurs when there is not a good electrical conductive path between them. Grounding and bonding of flammable liquid containers prevent static electricity from causing a spark. Recommended Practice on Static Electricity, NFPA Standard No. 77, should be consulted for details.

CLASSES OF FIRES

Up to this point, we have been discussing the causes of fires. Now we will examine the classes of fires. The National Fire Protection Association (NFPA) has defined four general classifications.

Class A Fires

Class A fires, sometimes called "surface burning fires," occur in ordinary combustible materials such as wood, cellulose, paper, cloth, excelsior, and rubber. Class A fires are extinguished by bringing the materials below their ignition temperature with the quenching and cooling effects of water. Under certain circumstances, these fires may be extinguished by the blanketing and smothering effects of dry chemical and carbon dioxide fire extinguishers.

Precautions

Because ordinary combustible materials serve as fuel for fire, several precautions are necessary:

1. Provide a program of adequate disposal of all combustible wastes and rubbish designed specifically for the operations or processes involved;
2. Provide for regular inspection of the waste storage area;
3. Provide a program of internal housekeeping that will prevent any accumulation of waste and which will result in safe, clean work areas;
4. Provide a program of external housekeeping to prevent accumulation of waste, brush, or high grass around buildings.

Several combustible substances deserve special mention: dusts, plastics, textiles, waste materials, and cleaning supplies.

Dusts. Most finely divided combustible materials in air present a serious hazard. Sawdust and coal dust are examples of combustible dusts. Deposits of combustible dust on floors, beams, machines, etc., are subject to flash fires, and dust suspended in air can explode violently. Prevention or removal of dust

accumulation on structural members, walls, and ceilings is a necessary procedure. Other precautions include:

1. Whenever possible, providing local exhaust systems for dust collection;
2. Providing a program for frequent vacuum cleaning of structural members, ceilings, and walls. The vacuum cleaning equipment should be explosive-proof;
3. Removing or controlling the accumulation of hazardous dust at all ignition sources.

Plastics. Ignited plastics, such as nitro-cellulose, polystyrene, cellulose, rayon, and polyvinyl chloride, are particularly dangerous because they produce large amounts of smoke and because their fumes are extremely toxic. Special care should be taken to keep plastics away from ignition sources.

Class B Fires

Class B fires are fires in flammable liquids, gases, and greases. Class B fires are most successfully extinguished by limiting the amount of air which supports combustion. Fire extinguishers of the dry chemical, carbon dioxide, foam, and halogenated hydrocarbon agent types are recommended for this class of fire. Solid streams of water are likely to spread the fire, but under certain circumstances, water fog nozzles prove effective.

Two terms are used in defining the temperature at which a liquid ignites: flash point and auto-ignition temperature.

Flash point is the minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid. Liquids with the lowest flash points are the most hazardous. Flash point temperatures cannot be considered constants, for they are related to other conditions. For example, the amount of vapor that will accumulate in the air above a volatile liquid depends upon two things:

1. Vapor pressure or the relative saturation of air with the vapor;
2. The surface area of the volatile liquid.

Auto-ignition temperature is the lowest temperature at which a flammable gas- or vapor-air mixture will ignite from its own heat source or a contacted heat surface without the necessity of a spark or flame. Vapors and gases will ignite spontaneously at a lower temperature in oxygen than in air. The majority of vapors and gases will not self-ignite in air until they reach temperatures of about 500°F to 900°F.

Flammable liquids have flash points below 140°F

and vapor pressures not exceeding 40 lb. per square inch at 100°F. Flammable liquids are hazardous because of their ease of ignition (low flash point), flammable range, and burning intensity. The degree of danger is determined largely by the flash point of the liquid, the concentration of vapors in the air, and the possibility of a source of ignition at or above a temperature sufficient to cause the mixture to burst into flame. Flammable liquids vaporize and form flammable mixtures when in open containers, when leaks or spills occur, or when heated. Gasoline, ethyl alcohol, benzene, turpentine, and naphtha are examples of flammable liquids. Fluid commodities containing flammable liquids (such as paints, varnishes, and cleaning solutions) should be considered flammable liquids and classed according to the flash point of the mixture.

Combustible liquids have flash points between 140°F-200°F. They are usually safe to handle and to work with at normal temperatures, but they should not be heated. Lubricating oils, kerosene, creosols, benzyl alcohol, cooking oil, mineral spirits, and palm oil are examples of combustible liquids.

Precautions

Because of their low flash point and low ignition temperatures, flammable liquids are dangerous and require several precautions.

Whenever possible, the use of highly flammable liquids should be avoided by using in their place nontoxic and nonflammable (or less flammable) liquids. For example, benzene can be replaced by toluene in most lacquers, synthetic rubber solutions, and paint removers.

Flammable liquids must be kept in approved fire-resistant safety containers, never in glass containers. All containers should be kept closed when not in use.

The amount of flammable liquids in the work area should be limited to that needed for one day.

Safe operating procedures, including local exhaust systems, should be established and enforced for all processes.

All ignition sources such as static electricity, smoking, and open flames should be removed or controlled.

Adequate clearances must be provided between flammable liquid containers or safety cans and any heat sources.

Adequate ventilation must be available for all operations involving the use or storage of flammable liquids.

Flammable liquid spills should be anticipated and

means provided to control and limit spillage, as well as suitable absorptive materials for use in cleaning up spills. All spills of flammable or combustible liquids should be cleaned up promptly.

Connections on all drums containing flammable and combustible liquids must be vapor- and heat-tight.

Flammable liquids must always be used and handled with extreme caution, no matter how familiar they are.

Large amounts of flammable liquids should be stored in a separate, fire-resistant building or vault that conforms to the recognized standards. Storage tanks should be properly vented and supported by masonry or, in diked areas, by poured concrete supports.

The hazards of *flammable gases* are generally the same as those of flammable liquids, except that commercial gases are usually in compressed gas cylinders. Flammable compressed gases usually burn with a greater intensity than exposed flammable liquids. Acetylene, propane, hydrogen, natural gas, and butane are examples of flammable gases.

Class C Fires

Class C fires occur in electrical equipment and call for such nonconducting extinguishing agents as dry chemical, carbon dioxide, and compressed gas. Fire prevention and protection for Class C fires will be discussed in the section on bonding and grounding.

Class D Fires

Class D fires occur in combustible metals such as magnesium, potassium, zirconium, lithium, sodium, powdered aluminum, zinc, and titanium. Special extinguishing agents and methods are used, such as graphite base types and sand. Precautions for combustible metals include:

1. Providing for frequent collection of combustible metal chips and shavings;
2. Preventing any presence of oil or grease near or in finely divided particles of combustible metals;
3. Providing covered, plainly labelled, clean, dry steel containers for combustible metals which are to be salvaged. They should be stored in an isolated storage yard or at a safe distance from all buildings.

FIRE PRECAUTIONS

Bonding and Grounding²

The words "bonding" and "grounding" are often

used interchangeably due to a misunderstanding of the two terms. The purpose of bonding is to eliminate a difference in potential between objects. The purpose of grounding is to eliminate a difference in potential between an object and ground. Bonding and grounding are effective only when the bonded objects are conductive.

Although bonding will eliminate a difference in electrical potential between the objects that are bonded, it will not eliminate a difference in potential between the objects and the earth, unless one of the objects has a ground to earth. Therefore, bonding will not eliminate the static charge. It will instead equalize the potential between the objects bonded so that a spark will not occur between them.

Petroleum liquids are capable of building up electrical charges when they flow through piping, when they are agitated in a tank or a container, or when they are subjected to vigorous mechanical movement such as spraying or splashing. Proper bonding and grounding of the transfer system usually drains off this static charge to ground as quickly as it is generated. However, rapid flow rates in transfer lines can cause very high electrical potentials on liquid surfaces, regardless of vessel grounding. Furthermore, some petroleum liquids are poor conductors of electricity, particularly the pure, refined products. Even though the transfer system is properly grounded, a static charge may build up on the surface of the liquid in the receiving container. The charge accumulates because static cannot flow through the liquid to grounded metal as fast as it is being generated. The accumulated static charge can result in a static spark with sufficient energy to ignite a flammable air-vapor mixture.

When flammable liquids are transferred from one container to another, they must be effectively bonded and grounded. This practice prevents electrical discharge (sparks) from the accumulation of static charge because of the transfer process.

Motor frames, starting or control boxes, conduits, and switches should be grounded in accordance with the requirements for installation of electrical and power equipment that are outlined in the National Electrical Code.

Moving belts are sources of static electricity unless they are made of a conductive material or are coated with a conductive belt-dressing compound designed to prevent the accumulation of static charges.

Ionization and the Control of Humidity

In addition to bonding and grounding, there are

two other ways that separated charges of static electricity may be recombined before sparking potentials build up.

First, the surrounding environment can be ionized. If the air in the immediate area is ionized with a charged body, a conducting path will be provided. Air can be ionized by using high-voltage or radioactive static eliminators.

Second, the humidity in the air can be controlled. Keeping the relative humidity in the area above sixty percent will condense enough moisture on the surface of the objects to allow static charges to dissipate.

Fire Protection Requirements for Storing Hazardous Materials

Special attention must be paid to fire protection requirements for storing flammable and combustible materials. Maintaining control over which chemicals are stored and how they are stored will result in chemical hazard protection.

Ventilation

Ventilation is an important part of chemical hazard protection and is required wherever hazardous substances are store.

Ventilation and/or exhaust must be maintained in all confined or enclosed workspaces to preclude concentrations of toxic or hazardous gases, vapors, and dusts exceeding maximum allowable limits.

In areas where neither adequate ventilation nor exhaust can be provided, personnel must be required to wear appropriate respiratory protection.

Purging Operations

Whenever a piece of equipment is laid up with nitrogen, argon, or CO₂ purge blanket, and could be entered by workers, all accesses must be barricaded and posted.

Workers introducing the purge will be responsible for assuring that the equipment is substantially sealed to prevent leakage to any unknown areas.

When the purge blanket is taken off and workers must enter to perform work, the confined space must be vented to an outside area where there are no confined spaces nor the possibility of accumulation.

Purging Systems for Welding Operations

When using argon, nitrogen or any inert gas to purge a system or line, all outlets throughout the entire line must be tagged, regardless of the areas through which the line penetrates. The tags should

show the name of the signing authority, date of the purge, and phone extension number.

For more detailed coverage of welding operations and the associated fire hazards and fire precautions, see Unit 13, "Hot Work."

Other fire precautions must also be taken in the confined workspace.

Access ladders, floors, components, etc., which require protective wrapping must be covered with flame-retardant material.

Flammable liquids, such as acetone, alcohol, etc., must be stored in UL listed approved flammable liquid containers, and the amount of these flammable liquids must not exceed the amount necessary to perform the work per day.

Proper fire extinguishers must be immediately available.

Cylinders containing oxygen, acetylene, or other fuel gases, are not to be taken into confined workspaces.

All rags, brushes, wipes, gloves, and so forth are to be stored in metal containers with lids.

Flammable gas equipment, hoses, and so forth must be free of defects and inspected by the user before each use.

Combustibles exposed to flames or sparks are to be removed before such operations or are to be adequately covered to prevent ignition.

For the elimination of possible fire in confined workspaces as a result of gas escaping through leaking or improperly closed torch valves, the gas supply to the torch must be positively shut off at some point outside the confined workspace whenever the torch is left unattended for a substantial period of time, such as during lunch periods. Overnight and at the change of shifts, the torch and hose must be removed from the confined space. Open-end fuel gas and oxygen hoses must be immediately removed from confined spaces when they are disconnected from the torch or other gas-consuming device. All gas manifold isolation valves must be closed at the end of the shift.

Communications should be maintained at all times with workers inside the confined space by workers outside these areas. This may be accomplished by using one or a combination of the following methods:

1. Visually, by a tender outside the area.
2. Vocally, by a tender outside the area.
3. By telephone—hard wire.
4. By electronic radio transmitter—FM. At no time should anyone enter a confined space

without at least one of the above means of communication.

PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers are the first line of defense in coping with fires of limited size. The National Safety Council lists six requirements for effective portable extinguishers.³ They must be:

1. A reliable type.
2. The right type for each class of fire that may occur in the confined space.
3. In sufficient quantity to protect against the exposure in the area.
4. Located where they are readily accessible for immediate use.
5. Maintained in perfect operating condition, inspected frequently, checked against tampering, and recharged as required.
6. Operable by any persons likely to be in the area who can locate them easily and who are trained to use them effectively and promptly.

Types of Portable Fire Extinguishers

Portable fire extinguishers can be divided into three basic categories: water, gaseous, and dry chemical. A dry powder type is available for Class D fires. Units are classified with a letter designation—A, B, C or D or a combination—to show which classes of fire they can combat effectively. Class A and B units also have a numerical rating that indicates their approximate extinguishing potential.

Water Types

Perhaps the most common portable fire extinguisher is the 2-1/2 gallon pressurized water unit, recommended for Class A hazards. This unit requires little skill to operate and has a long discharge time—usually about one minute—so that the inexperienced user has more time to fight a fire. It makes little noise and creates no clouds as do gaseous or dry chemical units. Water units are available in either stored-pressure or pump-tank models.

Stored-pressure units have a pressure gauge at the top. The entire main tank is pressurized with dry air or nitrogen. Although antifreeze can be added to water units, only the manufacturer's recommended solution should be used. As a rule, water units must be protected from temperatures below 40°F. Therefore, they are limited to indoor heated locations.

Pump-tank water units are not so common, but they are effective. These units have a double-action

pump that pushes water out as the operator pumps a plunger. They are not internally pressurized.

Aqueous Film-Forming Foam Type

A third water-base portable unit is available. It is filled with aqueous film-forming foam (AFFF). These 2-1/2 gallon stored-pressure units are unique because they are the only water-based portable units effective on Class A and B fires. Their primary ingredient is water, to which a foaming agent is added to form a premixed solution. The agent is effective on ordinary combustibles and flammable liquids, but the water base makes it a conductor of electricity. Therefore, these units are not suitable for Class C fires.

Gaseous-agent Types

There are two kinds of gaseous-agent portable extinguishers: carbon dioxide and halogenated hydrocarbon (Halon 1211 and 1301). Such extinguishers are especially effective on:

1. Gas and liquid flammable materials;
2. Electrical hazards, such as transformers or circuit breakers;
3. Engines using gasoline and other flammable fluids;
4. Ordinary combustibles, such as paper, wood, or textiles;
5. Hazardous solids.

Because gaseous agents leave no residue and dissipate readily, these extinguishers are used to protect costly equipment such as computers. They are ideal for use on small electrical fires and on fires in switchgear or electrical motors.

Portable carbon dioxide extinguishers are available in five- to twenty-pound sizes and may be recognized by their large, cone-shaped discharge horns. CO₂ gas is self-expelling, and these units are effective on Class B and C fires. CO₂ portable extinguishers have two major disadvantages:

1. The discharge is affected by wind and draft so that these units should be used only indoors and at close range;
2. The dilution of the oxygen in the air by the CO₂ concentration can create atmospheres that will not sustain life. Thorough ventilation is necessary after their use.

Halogenated extinguishers are among the newest portable units to be introduced. They are stored-pressure models and are most effective on Class B and C hazards. Larger units (those with more than nine pounds of agent) are rated for Class A fires as well. The major drawback of Halon portable

extinguishers is cost. Although they are extremely effective and clean to use, they are perhaps the most expensive units on the market.

Dry chemical units are designed for use on Class B and C fires. The notable exception is the multipurpose dry chemical (monoammonium phosphate), which is effective on Class A fires as well. These extinguishers are available in either stored-pressure or cartridge-operated units.

In the stored-pressure unit, an expellant (usually dry nitrogen, an inert gas) and extinguishing agent are stored in one chamber: discharge is controlled by a valve. A pressure gauge at the top of the unit indicates readiness for use. Normally, pressure ranges from 100 to 195 psig.

In cartridge-operated units, the expellant gas is stored in an auxiliary cartridge adjacent to the agent-containing shell. The unit is not pressurized until the cartridge is punctured. These units have no pressure gauge and must be weighed to determine their readiness for use. It is easier to recharge a cartridge unit than a stored-pressure unit, but the stored-pressure unit is more widely used. It is best for locations where infrequent use is anticipated and where skilled personnel with professional recharge equipment are available.

Though both regular and multipurpose dry chemical units are very effective fire fighters, duration time is short and the units are among the most sensitive to operator error.

The major disadvantage to the multipurpose dry chemical units are very effective fire fighters, duration time is short and the units are among the most sensitive to operator error.

The major disadvantage to the multipurpose dry chemical extinguisher is that the agent clings to hot surfaces and forms a sticky film. Cleanup is difficult. Therefore, this type of unit should not be located near delicate equipment or machinery that cannot be cleaned quickly and easily. If metal surfaces do become coated with monoammonium phosphate, they should be wiped with a wet cloth and dried as soon as possible to prevent rust or corrosion. Although regular dry chemical does not adhere to hot surfaces, it does leave a residue and should be brushed away as soon as possible after use.

Dry powder. Cartridge-operated portable units containing dry powder for use on Class D fires are available, but combustible metal fires present special problems. Each metal has distinctive burning characteristics that must be known before the fire can be combatted effectively. Dry powder fre-

quently is stored in a bucket with a shovel, in the vicinity of the combustible metal hazard. Should a fire occur, the burning metal must be covered with a layer of powder at least two inches deep. The National Safety Council's Data Sheet 1-567-79, Fire Protection for Combustible Metals, is an excellent source for further information.

Unit Placement

Becoming familiar with the kinds of units that are available is only the first step in understanding portable fire extinguishers. Placing the proper units in areas where they will be the most useful is also critical. Some of the factors to be considered are accessibility, visibility, ease of handling and appropriateness to the location.

Accessibility.

Extinguishers should be located close to likely hazards but not so close that they would be damaged by fire or be inaccessible were a fire to occur. For example, extinguishers should be located outside the door of a storage room rather than within the room itself, where they might become inaccessible. If the hazard is a dip tank, the fire extinguisher should not be mounted on the side of the tank. If the tank catches fire, the extinguisher is likely to be inaccessible. A better place for the unit is away from the tank on a wall or support column along normal paths of travel.

Visibility.

In general, for both accessibility and visibility, extinguishers should be placed at exits, where they can be used to fight fires while still allowing the fire fighter to escape. In this location, workers may see the extinguisher each time they enter or leave and will know where to find it if it is needed. Care must be taken, however, not to obstruct the exit in any way.

A fire extinguisher must not be blocked or hidden by stock, equipment or machinery. It must be located where it will not be damaged by equipment, corroded by chemical processes, or exposed to the elements. Its location should be made conspicuous. For example, if it is hung on a column or post, a red band can be painted around the post. The extinguisher must be kept clean. It should not be painted in a way that will camouflage it or obscure labels or markings.

Ease of Handling

For ease of lifting, extinguishers weighing less than forty pounds should be placed so that their

tops are not more than five feet above the floor. Extinguishers weighing more than forty pounds should not be more than 3-1/2 feet above the floor.

Appropriateness to the Location

The hazards of the confined space should be itemized. Where is a fire likely to start? What kind of fire is likely? How does the expense of the unit compare with the cost of cleanup? While it may be cheaper to install one dry chemical multipurpose unit instead of both a large water unit and a small Halon extinguisher, the less expensive unit may create a much greater problem with cleanup than the two separate units.

When units are placed, adjacent hazards should be considered. If a flammable liquid fire could ignite surrounding combustible paper and wood, the fire extinguisher selected should have both A and B capabilities. If nearby electrical equipment may catch fire, then the agent inside the extinguisher should be nonconductive.

Ambient temperatures may be important. If the storage area is unheated or only minimally heated, water units may freeze. A multipurpose dry chemical unit that will operate at temperatures from 40°F to 120°F is a better choice.

Unit Maintenance

Manufacturers of portable fire extinguishers work hard to make a product of high quality units and their components are tested before assembly. Most portable units are approved by Factory Mutual (FM) for the classes of fire for which they are suitable, or they are listed by Underwriters Laboratories (UL), rated for class of fire and extinguishing potential. Many units bear the seals of both testing agencies, whose quality control representatives inspect manufacturers periodically, exercising continual, careful control over the products they have approved or listed.

But any unit that is improperly maintained may pose a hazard. Carbon dioxide units, for instance, may explode if subjected to severe neglect and corrosion or if exposed to extremely high temperatures when the relief valve fails to operate.

Mixing different types of multipurpose dry chemicals may produce a violent reaction. An extinguisher that has been even partially discharged must be recharged with the same kind of chemical.

Monthly Inspections

Extinguishers should be inspected monthly to be certain of the following:

1. They are in their designated places.

2. Access and visibility are unobstructed.
3. The operating instructions on the extinguisher nameplate are legible and facing outward.
4. Any seals or tamper indicators that are broken or missing must be replaced.
5. They have no obvious physical damage, corrosion, leakage, or clogged nozzles.
6. Pressure gauge readings are in the operable range.

Water types without gauges should be hefted to determine fullness.

Annual Maintenance

Extinguishers should be maintained at least yearly or according to nameplate instructions. A tag must be attached to show the maintenance or recharge date and the signature or initials of the person performing the service.

Maintenance procedures should include a thorough examination of the three basic elements of an extinguisher:

1. Mechanical parts
2. Extinguishing agent
3. Expelling means.

Hydrostatic Testing

Every six years, stored-pressure extinguishers requiring a twelve-year hydrostatic test should be

emptied and serviced. The extinguisher sales representative will usually perform this service at appropriate intervals.

In this unit, we have examined the fundamentals of fire and their interaction. We have discussed twelve general causes of fires. We have looked in some detail at static electricity, one of the twelve. We have introduced the four classes of fire and described specific precautions for each class of fire. And, finally, we have described at great length types and uses of portable fire extinguishers.

Notes

1. Adapted from *Supervisors Safety Manual* (Chicago: National Safety Council, 1978), p. 371.
2. The sections on static electricity and on bonding and grounding are adapted from *Accident Prevention Manual*, pp. 1291-1295.
3. *Accident Prevention Manual*, p. 1343.

References

1. Information packets compiled by Bechtel Power Corporation for a new-employee training program (San Onofre Nuclear Generating Stations).
2. *Safety and Health in Industrial/Vocational Education* (Cincinnati: National Institute for Occupational Safety and Health), Unit 12, "Fire Protection."

Instruction Key—Unit 14

Fire Hazards and Fire Protection

Terms

1. Fire pyramid: a diagram illustrating the interaction of the four basic elements of a fire (fuel, oxygen, heat and an uninhibited chain reaction)
2. Conduction: the transfer of heat from one body or object to another through an intervening conducting medium, usually a solid
3. Convection: heat transmission by a circulating medium, either gaseous or liquid
4. Class A fires: those occurring in ordinary combustible materials such as wood, cellulose, paper, cloth, excelsior and rubber
5. Class B fires: those occurring in flammable liquids, gases and greases
6. Class C fires: those occurring in electrical equipment
7. Class D fires: those occurring in combustible metals
8. Bonding: a method of eliminating a difference in potential between objects
9. Grounding: a method of eliminating a difference in potential between an object and ground

Points for Discussion

1. Fundamentals of fire
 - a. the fire pyramid
 - b. removing one side of the fire pyramid
 - c. heat transfer
 - (1) direct contact with flame
 - (2) conduction
 - (3) convection
2. Sources of ignition
 - a. electrical failures and misuse of electrical equipment
 - b. smoking and matches
 - c. friction
 - d. overheated materials and hot surfaces
 - e. burner flames
 - f. spontaneous ignition
 - g. cutting and welding operations
 - h. exposure
 - i. incendiarism
 - j. mechanical sparks
 - k. chemical fires
 - l. static
3. Static electricity
4. Classes of fires
 - a. Class A fires
 - (1) dusts

- (2) plastics
 - (3) textiles
 - (4) precautions
- b. Class B fires
 - (1) flash point
 - (2) auto-ignition temperature
 - (3) flammable liquids
 - (4) combustible liquids
 - (5) precautions
- c. Class C fires
- d. Class D fires
5. Fire precautions
 - a. bonding and grounding
 - b. ionization and the control of humidity
 - c. fire protection requirements for storing hazardous materials
 - d. ventilation
 - e. purging operations
 - f. communications
6. Portable fire extinguishers
 - a. types of portable fire extinguishers
 - (1) water types
 - (2) aqueous film-forming foam type
 - (3) gaseous-agent types
 - (a) carbon dioxide
 - (b) halogenated hydrocarbon
 - (4) dry chemical
 - (5) dry powder
 - b. unit placement
 - (1) accessibility
 - (2) visibility
 - (3) ease of handling
 - (4) appropriateness to the location
 - c. unit maintenance
 - (1) monthly inspections
 - (2) annual maintenance
 - (3) hydrostatic testing

Questions

1. What is meant by the "uninhibited chain reaction" of a fire?
2. What is the major cause of fires?
3. What is the difference between bonding and grounding?
4. What are the principal hazards created by static electricity?
5. For which class of fire is the aqueous film-forming foam type portable fire extinguisher unsuitable and why?

Answers

1. It means simply that the fire will progress if nothing is done to impede its progress.
2. Electrical failures and misuse of electrical equipment account for a large number of fires.
3. While bonding will eliminate a difference in potential between objects, grounding eliminates a difference in potential between an object and ground.
4. Static electricity may lead to fire and explosion, which are caused when spark discharges containing sufficient energy ignite any flammable or explosive vapors, gases, or dusts that are present. Workers may also be subjected to shock, causing an involuntary reaction (such as a fall) which could result in injury.
5. The AFFF unit cannot be used on Class C fires because the water base of the agent makes it a conductor of electricity.

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UNIT 15

PHYSIOLOGICAL CONSIDERATIONS

The effects of atmospheric conditions encountered in confined workspaces on workers often manifest themselves in a variety of occupational illnesses.

BASIC PHYSIOLOGY¹

To begin, we will discuss briefly the physiology of the worker, setting the stage for an understanding of how various toxic agents affect his health.

RESPIRATORY SYSTEM

The respiratory system consists of three main parts (see Figure 15.1):

1. Air passages or airways, including the nose, mouth, upper throat, larynx, trachea, and bronchi;
2. The lungs, where oxygen is passed into the blood and carbon dioxide is given off;

3. The diaphragm and the muscles of the chest, which permit normal respiratory movement.

Logically, the term should include the circulatory system as well, since the two systems are jointly responsible for meeting the respiratory needs of the body, providing the mechanism whereby countless billions of cells are kept in contact with the external environment for access to oxygen and for elimination of carbon dioxide.

The basic role of the lungs and their related components is to provide rapid exchange of oxygen and carbon dioxide between the atmosphere and the blood coming to the pulmonary capillaries. The rate at which oxygen must be taken into the body (and proportional amounts of carbon dioxide released) varies depending on the amount of physical exertion that is taking place. If this wide range of need is to be met without significant change in the internal environment, the rates at which pulmonary

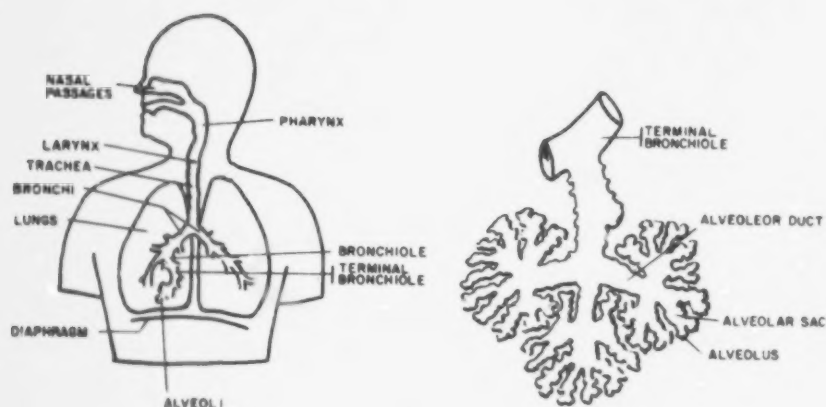


Figure 15.1. Reprinted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976) p. 10.

capillary blood is replaced and alveolar gas exchanged must change; these changes are accomplished by integrated responses of the cardiovascular system so that ventilation and perfusion of the alveolar surface is always closely matched.

Airways

The conducting portion of the respiratory system has a number of features which "condition" the air and protect the lungs from large infectious or noxious particles in the atmosphere. Some of these features are described briefly.

The mucous membrane of the nose protects against inhalation of large particles. It also absorbs soluble gases and moistens and warms or cools inhaled air. The sense-of-smell receptors in the upper reaches of the nose may also serve a protective function.

The tracheobronchial system is lined with cilia which force mucus secreted by mucosal glands toward the larynx. The mucus carries microorganisms and foreign particles, as well as macrophages which move out of the alveoli, often with material picked up from the alveolar surface. When the mucus reaches the pharynx, it is usually swallowed, but it may be expectorated. These mechanisms play an important role in preventing pulmonary problems caused by inhalation of dust, fume, and other hazardous materials in occupational exposure. The cough mechanism expels foreign materials from the tracheobronchial tree.

Other pulmonary responses occur in response to environmental exposures, but are less clearly protective. Most important of these is the bronchospasm, a response to many irritant gases. The partial or complete closure of bronchioles impedes access to the alveoli, but it does so at great cost to the worker's ability to breathe. Impeded gas exchange results in severe cases. An asthma-like response is a normal reaction to many inhaled irritants, but it may indicate a hyper-sensitivity so severe that further occupational exposure must be prevented.

Work of Breathing

Normally, the work of respiratory muscles in ventilating the lungs accounts for a very small part of the total oxygen demand of the body—normally less than three percent. This is not the case when resistance to gas flow in the air passage is increased by spasms in the bronchial tube or by excess secretion or when the lung is diseased. In such conditions, the increase of respiratory work may put a real burden on the entire cardiorespiratory system. Other conditions can also greatly increase the work of breathing; for example, the resistance of breathing through a gas mask.

Ordinarily, the respiratory muscles themselves are capable of performing the extra work required under such conditions. However, this is not true when respiratory muscles are weakened by disease such as myasthenia gravis or poliomyelitis, or by exposure to chemicals such as organophosphate pesticides.

Control of Respiration

Several factors in maintaining alveolar oxygen and carbon dioxide levels are known, some closely interrelated (oxygen, carbon dioxide, and hydrogen ion concentration), but no theory fully explains the hyperventilation which occurs in proportion to the level of exercise.

Excess carbon dioxide (as in contaminated atmospheres or rebreathing expired air) is a powerful stimulant, causing five- to ten-fold increase of respiration at five to seven percent carbon dioxide. The mechanism may be a direct carbon dioxide effect on respiratory nerve cells or an indirect effect of increased hydrogen ion concentration in the spinal fluid surrounding the nerve cells.

In oxygen-deficient atmospheres, the respiratory stimulation due to hypoxia is evident; the mechanism involving activation of specific receptor cells in the vicinity of the carotid arteries and the aortic arch is stimulated. The strength of this stimulus was misjudged for a long time because of the interrelationships among oxygen and carbon dioxide effects. Just as high carbon dioxide is a powerful stimulant, the loss of carbon dioxide is a potent depressant. Thus, the increase of respiration due to hypoxia eliminates carbon dioxide out of proportion to metabolic production; the level of carbon dioxide and the respiratory drive is inhibited.

THE CIRCULATORY SYSTEM

The heart and blood vessels transport blood throughout the body. The system is dual, the right side of the heart pumping blood only to the lungs while the left side pumps the freshly aerated blood to the rest of the body. The normal adult has about five quarts of blood; each side of the heart pumps at a rate of about five liters per minute at rest and can increase the output about five times during heavy exercise.

Veins

The venous system is the collecting system that connects the systemic capillary beds to the right side of the heart. About 50% of the total blood is at any time in the veins. Although veins are much thinner than arteries, they are elastic and they con-

tain smooth muscle. Therefore, they are not merely a passive collecting system; under nervous influence the overall tone of the system can increase, reducing volume and temporarily increasing venous return to the heart. This serves as an immediate transfusion to counter the effects of sudden loss of blood.

Pulmonary Circulation

Pulmonary circulation carries the same flow of blood as systemic circulation but is otherwise quite different. Pulmonary vascular pressures are generally much lower than systemic vascular pressures. Vasoconstriction and consequent local shunting are present in pulmonary circulation, but are much less developed than in systemic circulation. Diseases of the pulmonary circulation are usually secondary to extensive disease of pulmonary tissue, as in emphysema, fibrosis, and occupational lung diseases.

THE KIDNEYS

As emphasized earlier, proper cell function requires near-constancy of the internal environment—temperature, oxygen supply, nutrient supply, hydrogen ion concentration, and appropriate concentrations of water, sodium, potassium, calcium, magnesium, and other substances. The problem is to maintain constancy under the usual conditions of variations of intake and output of a substance. This involves the concept of balance: how is output of water (or sodium, or calcium) controlled so that the "right" amount is retained when intake is varied?

The kidneys play a major role in regulating body water, electrolytes, and other substances. These small organs receive nearly one-quarter of the output of the heart in serving this regulatory role.

THE DIGESTIVE SYSTEM

The function of the digestive system is to accept raw materials in the form of food, minerals, vitamins, and liquids in the external environment, to prepare such materials for absorption, and to absorb them into capillaries or lymphatics for distribution to the body. The system also has a limited role in excreting materials from the body.

Since the digestive tract is largely a tube open at both ends, in a real sense the contents of the gastrointestinal tract remain exterior to the body. In order to gain access to the body, ingested materials must pass through extremely acid conditions in the stomach and through a series of enzymes starting in the mouth and extending to the large intestine.

MODE OF ENTRY FOR TOXIC MATERIALS

In order for a hazardous substance to exert its toxic effect, it must come into contact with a body cell. There are three modes of entry for chemical compounds in the form of liquids, gases, mists, dusts, fumes, and vapors:

1. Ingestion (through the mouth);
2. Skin absorption;
3. Inhalation (through the lungs).

Ingestion

Of the three modes of entry, ingestion is the least common. A harmful amount of toxic material can be swallowed accidentally, but this is not common. Far greater is the likelihood of a worker ingesting toxic materials because of careless washing before eating, drinking, or smoking.

Inhaled toxic dusts can also be ingested in amounts that may cause health problems. Particles in inhaled air that are insoluble in the mucus of the respiratory tract may be carried to the mouth where they are either spit out or swallowed. If they are readily soluble in body fluids, toxic materials can be absorbed in the digestive system and picked up by the blood.

The fact that a substance has been swallowed does not necessarily mean that it will be absorbed. A certain selectivity prevents somewhat the absorption of unnatural substances. Materials not absorbed are eliminated directly through the intestinal tract. Food and liquid in the digestive tract dilute the toxic substance and may react with it to produce a harmless or insoluble substance. If the toxic substance is absorbed by the bloodstream, it will pass to the liver, which may alter and detoxify it, but which may possibly be damaged itself in the process.

The basic detoxification process involves the following steps:

1. Deposit in the liver;
2. Conversion to a nontoxic compound;
3. Transportation to kidney by way of blood stream;
4. Excretion through kidney and urinary tract.

Skin Absorption

The second mode of entry for hazardous materials is through skin absorption. Some substances are absorbed through the openings for hair follicles; others dissolve in the fats and oils of the skin. Of all occupational diseases, skin ailments are the most frequent. Dermatitis is the name given to any disease of the skin; dermatitis refers to any inflammation of the skin.

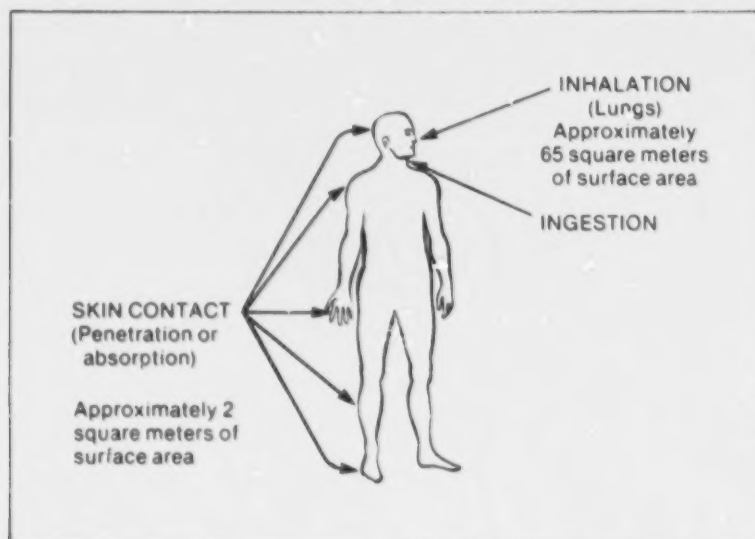


Figure 15.2. Adapted and reprinted with permission from Robert J. Firenze, *The Process of Hazard Control* (Dubuque, Iowa: Kendall/Hunt Publishing Co., 1978), p. 423.

Anatomy of the Skin

The skin is composed of two layers: the epidermis and the dermis. The epidermis is of primary concern in the occupational dermatoses.

The first layer of the epidermis is the fatty surface. This surface is composed of oil and perspiration and is easily washed off.

Under this layer lies the keratin layer. This layer is the chief barrier against water and aqueous solution and provides fair protection against attack by chemicals except for alkalis. Because it is composed of dead skin cells, this layer is constantly being replaced by new cells pushing to the surface from the deeper layer of the epidermis.

The dermis, or "true skin," is tough and resilient. It contains connective tissue and, if injured, can form new tissue to repair itself. The dermis is the major natural protection against trauma.

Causes of Skin Irritation

Physical agents which lead to dermatosis include heat, cold, and radiation. Hot water softens the skin so that substances attack it more readily. X-rays and other ionizing radiation may cause dermatosis,

severe burns, and even cancer. Prolonged exposure to sunlight, the most common source of sun-damaging radiation, produces skin changes which may cause dangerous body alterations.

Mechanical causes of skin irritation include friction, pressure, and trauma, including abrasions. If the outer layers of the skin become softened by such mechanical causes or by high temperatures and excessive perspiration, dermatosis may result. Friction may result in abrasion or, more commonly, a callus.

In industrial operations, *chemical agents* are the most frequent cause of dermatosis. Such chemicals can be divided into two groups: primary and secondary irritants.

Primary Irritants

Primary irritants react on contact, altering the chemistry of the skin. Such irritants cause a chemical reaction which may vary from severe burning to mild inflammation or irritation. About eighty percent of all occupational dermatoses are caused by primary irritants. The following are the broad categories of primary irritants.

Organic solvents irritate the skin because of their solvent qualities. They remove the natural oil from the skin, leaving it dry, scaly, and subject to cracking and infection. Examples of such organic solvents are trichloroethylene, acetone, and petroleum distillates used for degreasing and hand cleaning operations.

Detergents also remove the natural oils from the skin or react with the oils of the skin to increase susceptibility to chemicals that ordinarily do not affect the skin. Such detergents include alkalis and soap.

Desiccators, hygroscopic agents, and anhydrides take water out of the skin and generate heat. Examples are sulfuric acid, potash, and sulfur dioxide.

Protein precipitants coagulate the outer layers of the skin. Examples of protein-precipitating agents are alcohol, tannic acid, formaldehyde and phenol, and such heavy metal salts as the salts of arsenic, chromium, mercury, and zinc.

Oxidizers unite with hydrogen and liberate developing oxygen on the skin. Examples include chromic acid, hydrogen peroxide, chlorine, and ozone.

Secondary Irritants (Sensitizing Agents)

Some chemical substances produce no irritation on initial skin contact. After repeated or extended exposure, however, some individuals will develop an allergic reaction called sensitization dermatitis. A once-immune person may suddenly develop an allergic reaction to a particular substance.

This allergic reaction may come in the form of a rash or small water blisters and look like contact dermatitis. However, the skin reaction may occur at a site quite different from that where contact occurred. This causes some difficulty in determining precisely what agent is causing the reaction. Once a worker has become sensitized to a given material, the only sure way to prevent future allergic reactions is to avoid the material. In some cases, medication and desensitization by a physician may be possible.

Typical sensitizers include some epoxy resin amine hardeners, certain metals (such as chromium and nickel), and coal tar derivatives.

Some substances act as both primary and secondary irritants. These include such organic solvents as turpentine and the chlorinated phenols, chromic acid, formaldehyde, and epoxy resin components.

Preventing Dermatitis.

The best way to control dermatitis is to prevent

skin contact with the offending agents. If possible, chemicals of low toxicity and irritant potential should be substituted. Contact can be minimized by good personal hygiene, personal protective equipment, and barrier creams.

Good personal hygiene. Frequent and thorough washing with appropriate cleansers removes irritating substances before they can begin to cause problems.

Wherever solvents are used, good personal hygiene is important. Spills and splashes should be cleaned up immediately with soap and water. Clothing which has been splattered by chemical solvents should be replaced with clean clothing.

In the case of local *contact with acid*, the most important treatment is immediately to wash the affected area with large amounts of water. For minor contact, such as a splash on the hand, running tap water may be sufficient, provided that ample time is allowed for complete removal of the acid. Readily accessible, well-marked, rapid-action safety showers are required for the removal of acid from large areas of the body. A minimum of fifteen minutes should be devoted to removing all traces of acid.

A special *eye-wash* or *bath* should be provided. Adequate time for removal of acid should be allowed. This may necessitate repeated fifteen-minute washings while medical attention is sought.

The *type of soap* used in the plant is important. Even a generally good soap may cause irritation on certain types of skin. According to the National Safety Council, a soap should:

1. Be freely soluble in hard or soft, cold or hot water.
2. Remove fats, oils, and other soil without harming the skin.
3. Leave the natural fats and oils in the skin.
4. Contain no harsh abrasive or irritant scrubbers.
5. Be handy to use if in cake form or flow easily through soap dispensers if in granulated or powder form.
6. Stay insect-free.
7. Retain its properties in use.

Workers sometimes contract dermatitis by washing their hands in the wrong kinds of solutions. They should not be permitted to use solvents, even if they consider these cleaning agents the easiest to use and the fastest to work. They should be required to use the soap-dispensing units provided.

To keep dermatitis-causing agents from contacting the skin, the worker may need *impermeable*

protective clothing such as aprons, face shields, and gloves. But the worker must be aware that many solvents can penetrate rubber or neoprene gloves. Neoprene protects against most common oils and aliphatic hydrocarbons, but neither it nor rubber offers protection against the aromatic and halogenated hydrocarbons, the ketones, and many other solvents. For such uses, polyvinyl alcohol gloves provide protection, but these gloves must be kept away from water, acetone, and other solvents.

Barrier creams are the least effective way of protecting the skin. They should be used only to supplement good personal hygiene and personal protective equipment. Three main types of barrier creams and lotions are available:

1. Vanishing cream, which contains soap and emollients that coat the skin and cover the pores to make subsequent cleanup easier;
2. Water-repellent types (e.g., lanolin, petrolatum, organic silicones), which leave a water-insoluble film on the skin and thus repel water-soluble irritants;
3. Solvent-repellent types (e.g., methyl cellulose, sodium silicate, and tragacanth), which are insoluble in oils and solvents.

Barrier creams should be applied to clean skin. When the skin becomes soiled, both the cream and soil should be washed off and the barrier reapplied.

Inhalation

Up to now we have examined ingestion and skin absorption as modes of entry. The third mode of entry for chemical agents is inhalation. It is a particularly important mode of entry because of the rapidity with which a toxic material can be absorbed in the lungs, pass into the bloodstream, and reach the brain. If the same material is ingested instead of inhaled, it will be considerably diluted with the contents of the stomach. Inhalation hazards arise from excessive concentration of mists, vapors, gases, or solids that are in the form of dusts or fumes.

Inhalation is probably the most important route of entry in industrial situations. Some ninety percent of all industrial poisoning cases can be attributed to inhalation. Harmful substances may be suspended in the air in the form of dust, fume, mist, or vapor, and anything that is inhaled may present a serious health hazard.

Fortunately, not all foreign matter that is inhaled will be absorbed into the bloodstream. Some will be immediately exhaled. Some will become trapped

in the mucus lining of the air passages and later expectorated.

The total amount of a toxic substance absorbed depends on its concentration in the air, length of the exposure, and respiratory rate.

Respiratory Hazards

Depending upon the solubility of the material, inhalation of chemical agents may irritate the upper respiratory tract, including the mucous membranes, or it may harm the terminal passages of the lungs and air sacs. Inhaled contaminants fall into three general categories:

1. Particulates, such as asbestos fiber, which, when deposited in the lungs, may produce rapid local tissue damage, slower tissue reaction, disease, or physical plugging;
2. Toxic vapors and gases, such as hydrogen fluoride, that produce adverse reaction in the tissue of the lungs;
3. Toxic vapors and gases that do not affect the lung tissue locally but may either:
 - a. Pass from the lungs into the bloodstream, where they are carried to other body organs (examples: cadmium oxide fumes and solvents);
 - b. Affect adversely the oxygen-carrying capacity of the blood cells themselves (example: carbon monoxide).

TOXICOLOGICAL HAZARDS

Toxicology is the study of poisons: their effects, antidotes, and detection.

Nearly all materials could probably be said to be toxic. The level of toxicity of each material would depend largely upon how the material were used. However, some materials associated with operations in confined workspaces are inherently toxic. Therefore, we will examine the basics of toxic to understand more fully the effect of these materials on the human system.

Toxicity—A Definition

Toxic effects are disturbances of physiological functions caused by poisons or arising as side effects from some medications, vaccines, and exposures to chemicals.

Toxicity vs. Hazard

There is an important distinction between toxicity and hazard. Toxicity is generally regarded as a substance's capacity for producing unwanted effects at a sufficient concentration. Hazard is the probability that this concentration will be reached,

and many factors come into play here: route of entry, dosage, physiological stage, and environmental variables, among others.

Two chemicals may have the same degree of toxicity but different degrees of hazard if, for example, one of them has a strong disagreeable odor that warns of its presence and the other does not. There are many types of chemicals that produce effects on human tissues fairly indiscriminately, acting on all tissues or cells. Others act only on specific cells. Yet others are harmful only to certain species.

Types of Toxicity

One way to subdivide toxicity levels is on the basis of exposure duration.

Acute exposure means that the duration of exposure is relatively short. If the materials are inhaled or absorbed through the skin, it designates a single exposure measured in seconds, minutes, or hours. If the materials are ingested, it designates a single quantity or dose.

Subacute exposure refers to exposures of intermediate duration, those between acute and chronic. Generally, subacute exposures include durations up to approximately ninety days.

Chronic exposures are of long duration. If the materials are inhaled or absorbed through the skin, chronic exposures are prolonged or repeated exposures of a duration measured in days, months, or years. If the materials are ingested, chronic exposures are repeated doses over a period of days, months, or years. The term "chronic" does not necessarily refer to severity of symptoms. It does, however, imply exposures or doses that would be relatively harmless unless extended or repeated over long periods of time.

Distinguishing between exposures and effects is another way to designate toxicity. Some materials have a strong tendency to produce chronic illness even though the exposure may be acute. These materials include the heavy metals and most carcinogens. It goes without saying, of course, that their tendency to produce chronic sickness is accentuated if they are absorbed in repeated doses.

At the other extreme are compounds (such as cyanide) with which it is almost impossible to produce chronic illness, even though a single excessive dose may produce acute poisoning and may end quickly in death.

Most materials lie between these two extremes. Ordinary alcoholic intoxication is acute, but years of excessive drinking and the accompanying mal-

nutrition can produce chronic organic disease that remains even though no more alcohol is consumed.

The words *acute* and *chronic* as applied to illness are not indicators of severity, merely of duration. The common cold and the plague, for instance, are both acute illnesses. But while the first is mild, the second is potentially fatal.

Toxicity may also be divided into groups on the basis of where it affects the body.

Local effects are those taking place at the point of contact. This may be the skin, mucous membranes of the eyes, nose, mouth, throat, or anywhere along the respiratory or gastrointestinal system. Absorption does not necessarily occur.

Systemic effects occur at points other than the point of contact and presuppose that absorption has taken place. However, it can happen that a toxic agent might be absorbed through a channel such as the skin, lungs, or intestinal canal and later produce effects on one of those channels which are not a result of the original direct contact. Therefore, some agents produce harmful effects on a single organ or tissue as a result of both local and systemic actions.

The Dose-Response Relationship

The dose-response relationship may be expressed as the product of a concentration multiplied by the duration of exposure. The product is proportional to a constant. Therefore, the dose involves two variables: concentration and duration of exposure.

There are other factors which determine the presence or the absence of illness and its severity resulting from a particular exposure. These include:²

1. The route of exposure. It is important to learn whether the toxicant was ingested, inhaled, spilled onto the skin, or, as is usually the case, whether the exposure was caused by some combination of these.
2. The type of formulation or state of dispersion of the toxicant.
3. Temperature.
4. Humidity.
5. The physiological condition of the subject.
6. Interaction of the toxicant with other chemicals and drugs.

Interaction of chemicals may occur either in the external environment, such as when exposure to a mixture of two industrial chemicals occurs, or inside the patient, such as when previous dosage of a therapeutic drug may alter response to another foreign chemical. The latter type of reaction occurs with some frequency as a result of stimulation of the

drug-metabolizing enzyme system of the liver by various chemicals and drugs.

Threshold Limit Values

Threshold limit values (TLVs) are another way of expressing the level of toxicity of a chemical. They refer to airborne concentrations and represent conditions under which it is believed that nearly all workers may be repeatedly exposed for an eight-hour day, five days a week. It must be remembered, of course, that because of the wide variations in individual susceptibility, not all workers will be affected identically by the same TLV of a given substance. However, TLVs do provide useful guidelines.

For the most part, the TLVs are time-weighted average concentrations. Therefore, occasional excursions of short duration above the limit may be permissible, provided that they are compensated for by excursions proportionally below the limit during the same work day.

Similar to TLVs are the acceptable concentration standards published by the American Standards Association. According to the ASA, these standards are designed to prevent:

1. Undesirable changes in body structure or biochemistry;
2. Undesirable functional reactions that may have no discernible effects;
3. Irritation or other adverse sensory effects."

When the TLV refers to gases and vapors, it is usually expressed in parts per million (ppm)—i.e., parts of the gas or vapor per million parts of air.

When the TLV refers to fumes or mists, or to some types of dusts, it is usually expressed as milligrams per cubic meter or per 10 cubic meters of air.

For other types of dusts, the TLV is usually expressed in millions of particles per cubic foot of air.

There are three categories of Threshold Limit Values.

Time-Weighted Average (TLV-TWA) is the time-weighted average concentration for a normal eight-hour day or forty-hour week. Nearly all workers may be exposed day after day to airborne concentrations at these limits without adverse effect.

Short-term Exposure Limit (STEL) is the maximum concentration to which workers can be exposed for a period of up to fifteen minutes continuously without suffering:

1. Irritation;
2. Chronic or irreversible tissue change;

3. Narcoses of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency. No more than four fifteen-minute exposure periods per day are permitted, with at least sixty minutes between exposure periods.

Ceiling (TLV-C) is the concentration that should not be exceeded even for an instant.

Several points should be kept in mind regarding TLVs. Concentrations of chemicals rarely remain constant throughout the day. Most industrial environments contain mixtures of chemicals rather than single compounds. And because individual susceptibilities vary, control measures must be provided for those workers whose sensitivity is unusually high.

Threshold Limit Values—a copyrighted trademark of the American Conference of Governmental Industrial Hygienists—became Permissible Exposure Limits (PELs) when they were adopted by OSHA in 1970. These PELs represent the legal maximum level of contaminants in the air of the workplace.

Classes of Toxic Substances

One of the simplest methods of classification of toxic or otherwise harmful substances groups the substances into five categories.

Dusts are solid particles generated by handling, crushing, grinding, rapid impact, detonation, and decomposition of organic or inorganic materials such as rocks, ore, metal, coal, wood, grain, etc. Dusts do not tend to flocculate except under electrostatic forces; they do not diffuse in air, but settle under the influence of gravity.

Fumes are solid particles generated by condensation from gaseous states, generally after volatilization from molten metals, etc., and often accompanied by a chemical reaction such as oxidation. Fumes flocculate and sometimes coalesce.

Mists are suspended liquid droplets generated by condensation from the gaseous to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing, foaming, and atomizing.

Vapors represent the gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states by either increasing the pressure or decreasing the temperature alone. Vapors can and do diffuse.

Gases are normally formless fluids occupying the space. Gases may be changed to the liquid or to the solid state only by the combined effect of increased

pressure and decreased temperature. Gases, like vapors, diffuse.

Inhalation is probably the most important route of entry in industrial situations. Some ninety percent of all industrial poisoning cases can be attributed to inhalation. Harmful substances may be suspended in the air in the form of dust, fume, mist, or vapor, and anything that is inhaled may present a serious health hazard.

Fortunately, not all foreign matter that is inhaled will be absorbed into the bloodstream. Some will be immediately exhaled. Some will become trapped in the mucus lining of the air passages and later expectorated.

The total amount of a toxic substance absorbed depends on its concentration in the air, length of the exposure, and respiratory rate.

Absorption and Poisoning. While it is true that toxic substances must generally be absorbed to result in poisoning, it does not necessarily follow that absorption will always result in poisoning.

The human system is equipped with a variety of protective mechanisms. Some, such as the kidneys, allow the substances to pass virtually unchanged from the body with waste matter. Toxic gases are expired through the lungs.

Individual Susceptibility

It has long been known that there is a great deal of variability in the degree to which individuals will be affected by a given exposure. But as yet, not much is known about the factors that influence individual susceptibility.

Age, sex, and previous illnesses are likely to be significant factors. Others have been suggested but are not as well documented. These include:

- Different rates of working speed, resulting in variations in respiratory rate, in depth of respiration, and in pulse rate;
- The action of the cilia, the tiny hairs present in the cells lining air passages;
- The permeability of the lungs;
- The efficiency of the kidneys or of the liver;
- Nutritional habits;
- Alcohol consumption.

Allergy and Hypersensitivity

Any substance that produces an allergic reaction is called an allergen. An allergen affects only the susceptible individual.

Although allergy is specific, producing effects only on contact with one substance, it is possible for an allergy-prone individual to become class-

sensitized, meaning that if he is allergic to one substance, he may develop an allergy to related substances.

The individual's response to an allergen is generally a quantitative one: a small amount of the substance will produce slight symptoms; increasing amounts of the substance will produce increasingly severe symptoms. Merely decreasing the amount of the substance can usually bring relief. Time is also an important factor in the buildup of an allergic response. The longer an individual is exposed to a particular substance, the likelier he is to develop an allergy to it.

Effects of Toxic Exposures

Although industrial toxicology is usually concerned with the effects of low-grade sublethal exposures continued over a period of months or years, it is true as well that toxicological problems are frequently presented as a result of accidents that create sudden massive exposures to toxic compounds. Physiological responses to toxic materials depend upon the concentration and duration of exposure.

Irritation

Irritation may be any type of inflammation of any tissue with which the substance comes in contact. For many liquid irritants, the degree of local irritation is unrelated to their systemic toxicities.

The solubility of an irritant gas influences to a large extent the part of the respiratory tract that is affected. Gases that are very soluble in water irritate the nose and throat primarily because the moisture on the surface absorbs the gas. Other gases that are much less water soluble act mainly on the tissues in the lungs by travelling deep into the lungs before any significant absorption on moist surfaces can occur.

Some substances produce acute pulmonary edema, or fluid in the lungs, which usually begins as an immediate or intense irritation that leads later to coughing, dyspnea, cyanosis, or expectoration of large amounts of mucus. Sensitizing irritants induce asthmatic bronchitis.

Respiratory irritants may be inhaled in gaseous form, as a mist, or as particles with a coating of absorbed liquid.

Irritants may be divided into primary and secondary irritants. A *primary irritant* is a material that exerts little systemic toxic action either because the products formed on the tissues of the respiratory

tract are nontoxic or because the irritant action is far in excess of any systemic toxic action.

A *secondary irritant* produces irritant action of mucous membranes, but this effect is overshadowed by systemic effects resulting from absorption.

Irritation is normally a completely reversible phenomenon. By this we mean that if the victim is taken out of the exposure quickly enough, the condition of irritation will disappear with no residual damage.

Asphyxiation

The effects of asphyxiants are brought about by interference with oxygenation of the tissues with the result that the individual may suffocate. Asphyxiants can be divided into simple and chemical asphyxiants.

Simple asphyxiants are physiologically inert gases that act by diluting atmospheric oxygen below the level required to maintain blood levels sufficient for normal tissue respiration.

Asphyxiants deprive the body of needed oxygen which must be transported from the lungs via the bloodstream to the cells. With complete oxygen deprivation, the brain cells die in three to five minutes. Total asphyxiation leads to complete absence of oxygen in the blood (anoxia). Partial asphyxiation induces low levels of oxygen in the blood (hypoxia).

Because simple asphyxiants are not metabolized or changed to injurious chemicals, they do not cause chemical injury in the body. Therefore, they are neither toxic nor irritating. All that they do is decrease the oxygen level in the body far below what it should be.

Chemical asphyxiants either prevent the uptake of oxygen by the blood or interfere with the transport of oxygen from lungs to the tissues or prevent normal oxygenation of tissues, even though the blood is itself well oxygenated. This is done through direct chemical action.

Narcotics and Anaesthetics

Narcotic substances can produce unconsciousness and many of the same symptoms exhibited with asphyxiants. The distinguishing feature of narcotics is their effect on the central nervous system, causing it to fail in its normal functions.

Anaesthetics and narcotics exert their principal action by causing simple anaesthesia without serious systemic effects, unless the dose is massive. A successful anaesthetic will produce narcosis, but with a small margin for error.

PREVENTION/EMERGENCY PROCEDURES

Because of the variety of routes by which poisons may enter the body, emergency treatment will vary accordingly.

In all cases of poisoning, medical assistance should be summoned immediately. The names and telephone numbers of one or more on-call physicians, the nearest hospital, and an ambulance service should be posted near appropriate telephones.

Every workplace should be provided with at least one person on duty at all times who is trained to take charge in the event of a poisoning emergency. If possible, a sample of the suspected poison, or the container from which it came, should be saved for the guidance of the treating physician, the police, or the medical examiner.

Inhalation

The procedures for inhalation poisoning are as follows:

1. Remove the victim from the contaminated area. Rescuers should be properly protected or provided with life lines.
2. Keep the victim warm (but not too) and quiet. A supine position is generally best.
3. If the breathing has stopped, perform artificial respiration.
4. Administer oxygen, if it is available.
5. Clear all breathing passages. Examine mouth for false teeth and chewing gum and remove if present.

Ingestion

These are the emergency procedures for ingestion poisoning:

1. Attempt to empty the stomach by causing vomiting or using an emetic. This should be done even if a period of several hours has passed since the poison was swallowed. The exceptions here would be if corrosive chemicals such as strong acids or caustic alkalis have been ingested; if the victim is having convulsions; or if the victim is unconscious.
2. Dilute the poison by administering fluids in any of the following forms:
 - a. Three to four glasses of plain tap water.
 - b. Two to three glasses of soapy water.
 - c. One tablespoon of ordinary table salt to eight ounces of warm water.
 - d. Three to four glasses of milk. Dosage may be repeated several times if these fluids are vomited.
3. Give the victim the "universal antidote." A

mixture of one piece of powdered burnt toast and four tablespoons of milk of magnesia in a cup of strong tea will absorb and neutralize many poisons.

Skin Contact

If the poison has been splashed onto the skin, these measures should be followed:

1. Dilute the contaminating substance with large amounts of water. This is best done in a shower, but may also be done with a hose, large buckets, or other means. The water should be lukewarm if possible.
2. Remove contaminated clothing. Those assisting the victim should protect their own skin with gloves.
3. Chemical burns of the eye should be treated with large amounts of water or with a solution of one level teaspoonful bicarbonate soda to one quart warm, clear water.

HEAT STRESS

Heat stress is a very complex product of numerous factors, each one affecting individuals in a slightly different way. The principal factors in heat stress are:

- Environmental temperature
- Humidity
- Radiant heat
- Work effort
- Air movement

Heat stress is the aggregate of environmental and physical work factors that constitute the total heat load imposed on the body. Factors of heat stress are the air temperature, radiant heat exchange, air movement, and water vapor pressure. Physical work contributes to heat stress by producing metabolic heat in the body in proportion to the intensity of the work. The amount and type of clothing worn also affect the heat stress.

HEAT LOSS³

Heat is exchanged between the body and the environment by an increase in blood circulation near the surface of the skin. If overheating continues, the evaporation of sweat from the skin's surface, an effective and uniquely human procedure, increases heat loss.

Heat Loss by Radiation

Heat is exchanged by radiation between the surface of the body and all of the surfaces in its surroundings which are at temperatures different from its own.

Heat Loss by Convection-Conduction

The rate of heat exchange by convection-conduction depends on skin temperature, air temperature, and insulation value of the clothing and air surrounding the skin. The insulation value of the air-clothing system will vary with the rate of air movement.

The rate of evaporative heat loss is determined basically by the difference between the effective vapor pressure of the water on the skin and that of the air. But movement of the air greatly accelerates the rate of loss, so that the combined process is properly termed *evaporation-convection*.

As environmental temperatures approach normal skin temperature, the job of cooling the body becomes more difficult. Blood brought to the body surface cannot shed its heat if air temperatures are as warm as, or warmer than the skin. Under these conditions, the heart continues to pump blood to the surface, but the release of fluid onto the skin by the sweat glands becomes almost the only effective means of maintaining a constant body temperature.

The difficulty worsens when the humidity is high. Sweating does nothing to cool the body unless the moisture is removed from the skin by evaporation--and high humidity retards evaporation.

HEAT-INDUCED ILLNESSES

There are four major categories of heat-induced illnesses: heat exhaustion, dehydration, heat cramps, and heat stroke. Each of these conditions requires immediate medical assistance by trained professionals.

Heat Exhaustion

Heat exhaustion includes several clinical disorders, all of which display similar symptoms. It is not directly the result of heat regulation, but rather of an inability to adjust to the heat regulation. The condition is caused by the loss of fluid in sweating, sometimes by the loss of body salt, and often by both. The worker with heat exhaustion experiences extreme weakness or fatigue, giddiness, nausea, or headache. In more serious cases, the victim may vomit and/or lose consciousness. The skin is clammy and moist, the complexion pale or flushed, and the body temperature normal or slightly higher. The unacclimatized, the physically unfit, and the obese are especially prone to developing heat exhaustion. Major factors that may bring about this condition include:

1. Increasing vascular dilation and decreasing capacity of the circulation to meet the demands for heat loss to the environment, exercise, and digestive activities;
2. Decreasing blood volume by dehydration, collection of fluids in tissues, adrenal insufficiency, or lack of body salt;
3. Cardiac weakness as a result of emotional upheaval, malnutrition, lack of physical training, infection, alcohol or drug abuse, or cardiac failure.

Dehydration

In its early stages, dehydration acts mainly by reducing the blood volume and promoting heat exhaustion. But in extreme cases, it brings about disturbances of cell function which interact amongst each other to deteriorate the general condition of the organism. Lack of muscular control, reduced secretion of body fluids (especially of the salivary glands), loss of appetite, difficulty in swallowing, acid accumulation in the tissues, and nervous irritability followed by depression, will occur in increasing severity, while uremia and fever may end in death.

Heat Cramps

Heat cramps are painful spasms of the working muscles of those who sweat profusely in heat, who drink large quantities of water, but who fail to replace their bodies' salt loss. The drinking of water tends to dilute the body's extracellular fluids, while salt continues to be lost. Soon, the low salt in the muscles causes painful cramps.

Heat Stroke (Hyperpyrexia)

Heat stroke is the most serious of health problems while working in hot environments. It occurs when the human thermo-regulatory system simply breaks down under stress, and sweating stops. There may be little warning to the victim that a crisis stage has been reached. Precisely why this happens is not known, but when it does, the body's only effective means of getting rid of excess heat is gone.

A heat stroke victim's skin is hot, dry, and usually red or spotted. Body temperature is 105° or higher and rising. He is mentally confused, irritable and may complain of feeling chills. If the worker is not taken out of the hot environment at this early stage of heat stroke and cooled off rapidly, more severe symptoms will occur, such as unconsciousness, delirium, and convulsions, leading to death.

Fainting

A worker who is not used to hot environments and who stands erect and immobile in the heat may simply black out. With enlarged blood vessels in the skin and in the lower part of the body, blood may pool there rather than returning to the heart to be pumped to the brain. Once lying down, the worker should soon recover. By moving around, and thereby preventing blood from pooling, further fainting can be prevented.

Heat Rash

Heat rash, also known as "prickly heat," is likely to occur in hot and humid environments where sweat is not easily removed from the surface of the skin by evaporation. The sweat ducts are plugged and the sweat glands inflamed. A rash soon appears. When extensive, or when complicated by infection, prickly heat can be so uncomfortable as to reduce a worker's performance. This condition can be prevented by resting in a cool place at regular intervals and by taking a shower after each workshift.

Transient Heat Fatigue

Transient heat fatigue refers to the state of discomfort and psychological strain arising from prolonged heat exposure. Workers unused to the heat are particularly susceptible, and can suffer, to varying degrees, a decline in task performance, coordination, alertness, vigilance, irritability, and depression. The severity of transient heat fatigue can be lessened by a period of gradual adjustment to the hot environment.

SAFETY HAZARDS IN HOT ENVIRONMENTS

Certain safety problems are common to hot environments. Heat tends to promote accidents due to the slipperiness of sweaty palms, dizziness, or the fogging of safety glasses. And wherever hot surfaces, molten metal, steam, etc., exist, the possibility of burns from accidental contact also exists. Such mishaps are often caused by some secondary agent, such as water suddenly escaping into molten metal or the malfunction of pressure relief valves on water heaters and the like; in both cases a stream of hot steam can hit the worker in unprotected areas of the skin and cause burns.

But aside from these obvious dangers, the frequency of accidents, in general, appears to be higher in hot environments. One reason is that physical performance and mental alertness are lowered in heat. Increased body temperature and physical dis-

comfort help promote irritability, anger, and other emotional states which sometimes cause workers to commit rash or careless acts or to divert attention from hazardous tasks. A worker's psychological state usually will have a substantial effect on safe performance.

In this unit, we have outlined the basic physiology of systems affected by environmental hazards. We have introduced the three modes of entry by toxic substance into the system. And we have discussed various illnesses occurring in response to environmental hazards.

Notes

1. Adapted from *The Industrial Environment—Its Evaluation and Control* (Washington, D.C.: National Institute for Occupational Safety and Health, 1973) Chapter 6, "Review of Physiology" by James L. Whittenberger, M.D.
2. Adapted from *Dangerous Properties of Industrial Materials* (New York: Van Nostrand Reinhold Company), 4th ed., copyright 1975. Section 9, "Toxicology," by William F. Durham, Ph.D., pp. 291-292.
3. Adapted from *Industrial Hygiene Measurements* (Cincinnati: National Institute for Occupational Safety and Health, August 1979) Section 5, "Heat Stress," prepared by Austin F. Henschel, Ph.D.

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1. *Hot Environments*, NIOSH publication no. 80-132.
2. Olishifski, Julian B., Editor-in-Chief, *Fundamentals of Industrial Hygiene* (Chicago: National Safety Council), 2nd ed., copyright 1979. Chapter 15, "Industrial Toxicology," by Ralph G. Smith and Julian B. Olishifski.
3. Patty, Frank A., *Industrial Hygiene and Toxicology* (New York: Interscience Publishers, Inc.) Second revised edition, copyright 1948, 1958. Chapter VI, "The Mode of Entry and Action of Toxic Materials," by Frank A. Patty.
4. Sax, N. Irving, *Dangerous Properties of Industrial Materials* (New York: Van Nostrand Reinhold Company), 4th ed., copyright 1975 by Litton Educational Publishing, Inc., Section 9, "Toxicology," by William F. Durham.
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6. Firenze, Robert J. and James B. Walters, *Safety and Health for Industrial/Vocational Education for Supervisors and Instructors* (Cincinnati: National Institute for Occupational Safety and Health, July 1981) Unit 13, "Health Hazards."

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Instruction Key—Unit 15

Physiological Considerations and Toxicological Hazards

Terms

1. Primary irritants: substances that react on contact, altering the chemistry of the skin
2. Secondary irritants: substances that produce no effects on initial skin contact, but that may cause allergic reactions to develop after repeated contact
3. Threshold limit value: an exposure level to airborne substances under which most people can work
4. Time-weighted average: the average permissible concentration for a normal eight-hour day or forty-hour week
5. Short-term exposure limit: the maximum concentration to which workers can be exposed for a period of up to fifteen minutes
6. Ceiling: a concentration that should not be exceeded even for an instant
7. Toxicity: the capacity of a substance for producing unwanted effects at sufficient concentration
8. Hazard: The probability that a dangerous concentration of a given chemical will be reached
9. Acute exposure: an exposure of relatively short duration
10. Subacute exposure: an exposure of intermediate duration
11. Chronic exposure: an exposure of long duration
12. Simple asphyxiants: substances that interfere with the body's capacity for utilizing oxygen

Points for Discussion

1. Review of physiology
 - a. Respiratory system
 - 1) Features
 - 2) Function
 - b. Circulatory system
 - c. Kidneys
 - d. Digestive system
2. Modes of entry for toxic materials
 - a. Ingestion
 - b. Skin absorption
 - 1) Physical agents
 - 2) Mechanical agents
 - 3) Chemical agents
 - 4) Primary irritants
 - 5) Secondary irritants
 - 6) Preventives
 - c. Inhalation

3. Toxicological hazards
 - a. Toxicity vs. hazard
 - b. Types of toxicity
 - 1) Acute
 - 2) Subacute
 - 3) Chronic
 - c. Local effects
 - d. Systemic effects
 - e. The dose-response relationship
4. Threshold limit values
 - a. Time-weighted average
 - b. Short-term exposure limit
 - c. Ceiling
5. Classes of toxic substances
 - a. Dusts
 - b. Fumes
 - c. Mists
 - d. Vapors
 - e. Gases
6. Absorption and poisoning
 - a. Individual susceptibility
 - b. Allergy and hypersensitivity
7. Effects of toxic exposures
 - a. Irritation
 - 1) Primary irritant
 - 2) Secondary irritant
 - b. Asphyxiation
 - 1) Simple asphyxiants
 - 2) Chemical asphyxiants
 - c. Narcotics and anaesthetics
8. Prevention/emergency procedures
9. Heat loss
 - a. By radiation
 - b. By convection-conduction
10. Heat-induced illness
 - a. Heat exhaustion
 - b. Dehydration
 - c. Heat cramps
 - d. Heat stroke

Questions

1. What is the basic role of the lungs and their related components?
2. Of the three modes of entry, which is the least common? The most?
3. Explain the difference between a primary and a secondary irritant.
4. Give an example of a situation in which two chemicals might have the same degree of toxicity but different degrees of hazard.

5. What are some variables affecting individual susceptibility to a given toxic exposure?
6. What are the two major functions regulating normal body temperatures?
7. What environmental conditions will reduce the effectiveness of these functions?
8. Why is the cessation of perspiration so serious in heat stroke?

Answers

1. They provide rapid exchange of oxygen and carbon dioxide between the atmosphere and the blood coming to the pulmonary capillaries.
2. Surprisingly, ingestion is not nearly as common as is generally thought. It is the least common mode of entry in construction. Inhalation is the most common mode of entry, because hazardous substances can easily become suspended in the air.
3. Primary irritants react on contact, altering the chemistry of the skin and producing an immediate reaction. Secondary irritants may produce no effects on initial contact with the skin, but cause allergic reactions with repeated exposures.
4. If one of the two chemicals has a strong disagreeable odor, while the other does not, the first chemical is less likely to reach a hazardous concentration because it will be more easily detected. Thus, the hazard of the first chemical is less than that of the odorless chemical, even if the two are equally toxic.
5. The variables include all of the following: age, sex, previous illnesses, differing rates of respiration and pulse, permeability of the lungs, the efficiency of the kidneys or of the liver, nutritional habits, and alcohol consumption.
6. Blood circulation and perspiration keep the body's temperature regulated under normal conditions.
7. External temperatures approaching those of normal skin temperatures mean that blood brought to the body's surface cannot release its heat into the air. And high humidity retards evaporation of perspiration from the skin.
8. It means that the body's only effective means of releasing excess heat has broken down. The body temperature will quickly reach a dangerously high level and continue to climb until the worker is removed and cooled off rapidly.

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UNIT 16

NOISE

Everyone is at some time exposed to noises that have the potential to damage the hearing. Ordinary construction noises—for example, those produced by compressors and machinery—can cause hearing damage if the exposure time is long enough. Noises at high levels of intensity do not require lengthy exposure time to cause hearing damage.

To understand how hearing can be damaged by noise, we must first understand something about both the nature of sound and the process of hearing.

NATURE OF SOUND

Sound travels through the air in the form of a series of moving pressure disturbances or waves. These pressure waves, caused by minute back-and-forth movements of the air molecules, are formed by the vibration or motion of the sound source.

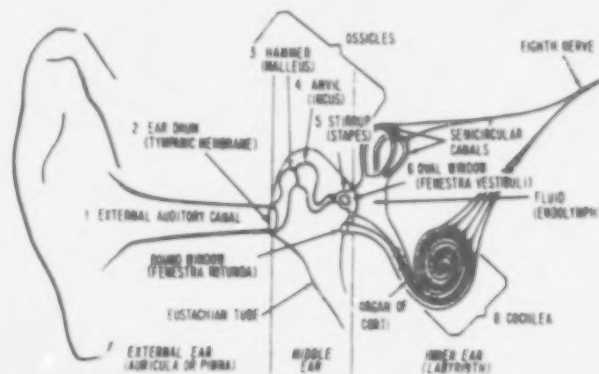
As the energy is transmitted, the pressure variations reach the eardrum, and the vibrations are

translated by the hearing system into a sensation called sound.

PROCESS OF HEARING

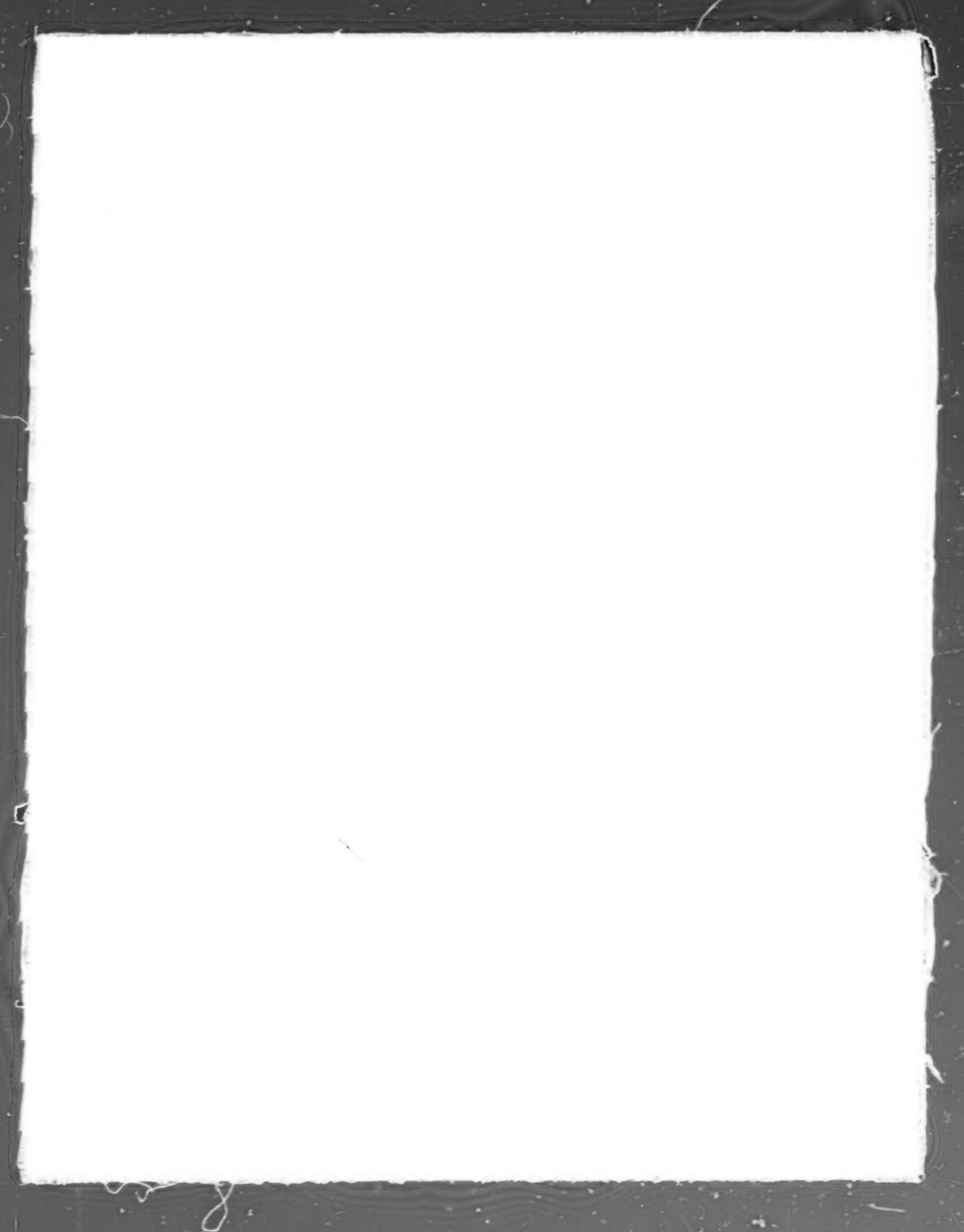
Figure 16.1 traces the path of a sound from its source inside the body through the air to the brain.

1. Sound waves enter the external auditory canal (1) and are directed to the eardrum or tympanic membrane (2), causing it to vibrate.
2. The eardrum passes the vibrations to the three small bones located within the middle ear: the hammer or malleus (3), the anvil or incus (4), and the stirrup or stapes (5).
3. These three small bones pass the vibration along to the oval window (6), which is connected to the inner ear. The major components of the inner ear are the vestibular system or semicircular canals (7) and the cochlea (8), a small snail-shaped bony structure filled with



-How the ear hears. Wave motions in the air set up sympathetic vibrations which are transmitted by the eardrum and the three bones in the middle ear to the fluid-filled chamber of the inner ear. In the process, the relatively large but feeble air-induced vibrations of the eardrum are converted to much smaller but more powerful mechanical vibrations by the three ossicles, and finally into even stronger fluid vibrations. The wave motion in the fluid is sensed by the nerves in the cochlea, which transmit neural messages to the brain.

Figure 16.1. Reprinted with permission from American Foundrymen's Society.



fluid and lined with tiny hair cells. The oval window passes the vibrations along to the fluid in the cochlea, which in turn stimulates the hair cells in the cochlea.

4. The hair cells charge the vibrations to electrical signals which are carried to the brain and identified by the brain as sound.

CHARACTERISTICS OF SOUND

Sound may be defined in terms of its two basic characteristics, pitch and intensity.

Pitch

Sound travels through the air in the form of pressure disturbances or waves. The frequency with which the waves strike the ears determines the pitch of the sound. The higher the frequency of the waves, the higher the pitch of the sound.

Within a sound wave, each pressure disturbance or back-and-forth movement of the air molecules is referred to as a cycle of the wave. The frequency of sound waves can therefore be measured in terms of the number of cycles per second (CPS) that are generated by a sound source. The unit commonly used to designate frequency is the hertz (Hz). One hertz is equivalent to one cycle per second.

A sound source vibrating rapidly—for example, 10,000 times per second (10,000 Hz)—is a sound of relatively high pitch, very near the upper limit of human hearing. A sound source vibrating slowly—for example, 200 times per second (200 Hz)—will produce a sound of relatively low pitch.

Intensity

Intensity, the second characteristic of sound, is what is commonly identified as volume. While the pitch of a sound is determined by the frequency of the waves, the intensity of a sound is determined by the size of the air pressure disturbance. A larger pressure disturbance results in a sound of higher intensity; a smaller pressure disturbance results in a sound of lower intensity.

Air pressure disturbance of sound waves is measured in units called *decibels (dB)*. The higher the number of decibels, the greater the pressure disturbance and the more intense the sound. The sound produced by a gasoline-powered lawnmower, at about 90 decibels, would be considered high intensity; the sound of leaves rustling, at about 20 decibels, would be considered low intensity.

Everyone has what is known as a *threshold of hearing*, the sound level below which no sounds are heard. For most young people with normal hearing sensitivity, this threshold of hearing occurs near

zero decibels. The decibel scale was developed so that its zero point would coincide approximately with the threshold of hearing.

Noise at high levels of intensity can raise this threshold so that sounds at lower decibel levels cannot be heard, sounds that normally can be heard. This may occur either temporarily or permanently.

A *Temporary Threshold Shift (TTS)* is a condition in which the ability to hear sounds at lower decibel levels is temporarily lost. The TTS occurs during exposure to potentially damaging noise. The TTS is noticed after the noise has subsided or ceased. At this point, certain lower decibel sounds normally easy to hear may now be more difficult to hear or perhaps cannot be heard at all.

This threshold shift is the result of damage to the tiny hair cells within the cochlea. These are the cells that ultimately transmit sound to the brain in the form of electrical impulses. When these cells are damaged, the brain does not receive sound signals.

Intense noise damages the hair cells by overstimulating or overloading them, thus weakening their ability to transmit signals to the brain. Given an opportunity to recover (that is, being removed from the source of the damaging noise), the hair cells generally will do so. Following a recovery period, usually a few hours, the threshold of hearing will return again to its normal level.

But this return to a normal threshold level does not always occur. When it does not, a *Permanent Threshold Shift (PTS)* has taken place and the ability to hear sounds at lower decibel levels is permanently lost. One of the most harmful effects of such a hearing loss is that some of the ability to understand speech is lost. A PTS occasionally results from a single damaging exposure to very high intensity noise, but most often it results from exposure to moderately intense noise over an extended period of time.

Unfortunately, gradual hearing loss is often noticed only after permanent damage has been done.

A PTS can be the result of a series of temporary threshold shifts, each of which weakens the hair cells in the cochlea. The cumulative effect of the temporary shifts can be that the hair cells are actually destroyed. At this point, recovery is not possible. The lower decibel sounds will never again be heard. After the first permanent hearing loss has been detected, further hearing losses can occur so long as exposure to damaging noise at higher levels continues.

No one can predict when a Temporary Thresh-

old Shift will become a Permanent Threshold Shift. However, the ears themselves can detect noise levels sufficiently intense to cause permanent hearing loss on relatively short exposure.

Warning signals, such as a ringing in the ears ("tinnitus"), a threshold shift lasting more than a few hours, or a tickling sensation in the ears (which is actually a mild form of pain) indicate that removing from exposure to high intensity noise would be wise. These warning signals also indicate that, before returning to the proximity of the high intensity noises, steps should be taken to protect the hearing.

Unfortunately, permanent hearing loss can often result from long-term exposure to noise levels below the range at which warning signals are perceived. It takes longer for hearing to be damaged by noise at these lower levels, but the result is much the same.

Regardless of the presence or absence of warning signals, hearing tests should be part of a routine physical examination. A hearing test can detect the early signs of a hearing loss before more serious damage occurs.

HOW NOISE DAMAGES HEARING

How intense noise must be before it has the potential to damage the hearing, either temporarily or permanently, cannot be stated categorically. There are too many variables involved. The danger that noise poses to the hearing is a function of the interaction of four major variables.

Sound Level

Let us examine the first variable, the level of noise.

For most persons, the threshold of hearing occurs near 0 decibels, usually between 0 and 10 decibels. Sounds below approximately 40 decibels are considered low intensity noises. Examples include the rustling of leaves, a whisper, and the ticking of a watch.

Sounds between 40 and 70 decibels are considered moderate in intensity and include such things as conversational speech and a typewriter.

Sounds between 70 and 90 decibels are considered loud and include such things as a dishwasher and a table saw.

Sounds between 90 and 100 decibels are considered intense and include such things as a gasoline-powered lawnmower, a rock band, and an emergency siren.

Sounds between 110 and 130 decibels may induce

pain in the ears. Examples include nearby thunder, sonic booms, and jet plane takeoffs.

At the higher decibel levels (80-90 and above), the likelihood of noise-induced hearing damage begins to increase if an individual is exposed to noise at or above these levels for a sufficient length of time.

Some machinery produces these higher decibel noises. Examples include:

Machine	dB
Punch Press	96-108
Hydraulic Press	130
Circular Saw	105
Wood Planer	98-110
Oxygen Torch	121

Duration of Exposure

The second variable affecting potential hearing damage is duration. The higher the intensity of the noise, the shorter the time required for hearing damage to occur. Conversely, the longer the duration of exposure, the lower the intensity required to cause hearing damage.

OSHA Standards

The following table shows the permissible sound exposures established by OSHA.

Hours per Day of Exposure	A-Weighted Sound Level, dB
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

Reprinted from *General Industry OSHA Safety and Health Standards* (29 CFR 1910.95). U.S. Department of Labor, November 1978.

In this table, sound level is designated "A-weighted." A-weighting is a sound measurement technique that filters out the low-frequency sounds which the human ear does not hear well, thus

roughly simulating the sensitivity of the human ear to sound frequency.

The table indicates that workers should not be exposed to a sound level in excess of 90 dB, on the average, for an eight-hour day. If such exposure cannot be avoided, steps must be taken to protect the worker's hearing.

The table also indicates that workers should not be exposed to a sound level which exceeds 115 dB, on the average, for even fifteen minutes of a work day. Workers should never be exposed to steady sound levels above 115 dB.

It should be noted that the OSHA standards presented in this table apply only to working environments. Hearing is affected by day-to-day noise exposures as well.

Recovery Periods

This brings us to a third variable which determines how noise can damage the hearing: the number and length of quiet (recovery) periods between periods of sound.

If work is to be performed in a noisy environment in which it is possible to experience threshold shifts, extended contact with noisy environments outside the environment must be avoided. Using power shop tools or lawnmowers or attending rock concerts prevents hearing recovery from the effects of day-long noise exposure.

EPA Recommendation and Goal

Another government agency concerned with the damaging effects of noise has recommended lower levels of safe noise exposure. The Environmental Protection Agency (EPA) recommends that, for an eight-hour work day, workers not be exposed to A-weighted noise levels averaging greater than 85 dB.

The EPA goal exceeds even its own recommendation. Its goal is to reduce that noise level to an average no greater than 75 dB for an eight-hour work day. Further, the EPA believes that, over an entire 24-hour day, individuals should not be exposed to A-weighted noise levels averaging greater than 70 dB. This means that, if a worker is exposed to an average 75 dB while at work, the noise exposure for the sixteen-hour balance of the day should be low enough to bring the overall 24-hour average noise exposure down to the 70 dB level.

Individual Differences

The difficulty in stating precisely what should be an adequate margin of safety for all persons in all types of jobs brings us to the fourth variable affect-

ing potential hearing damage, individual differences. The fact that one worker does not report any hearing difficulty resulting from work in a noisy environment does not mean that another worker will not suffer hearing damage in the same environment.

SOURCES OF NOISE ON THE WORK SITE

Construction workers are exposed to high noise levels from three basic sources:

1. Equipment operated by workers;
2. Equipment operated adjacent to workers;
3. The work site as a whole.

While there are many different pieces of equipment present on most work sites, they can be grouped into three broad categories for purposes of noise analysis:

1. Equipment powered by internal combustion engines;
2. Impact equipment and tools;
3. General equipment.

Most of the steady noise level of the work site is generated by *internal combustion engines*—usually diesel. The A-weighted levels of noise generated by diesel engines fall in a range between approximately 73 and 96 dB (heard at 50 feet).

Impact equipment is usually powered by steam or by diesel. In impact equipment, noise comes from two sources: the power supply and the impact of the equipment on the work surface.

With steam and diesel engines, the combination of the power supply exhaust and the toolwork (the impact) will produce A-weighted noise levels ranging from 95 to 105 dB at 50 feet.

Most *impact tools*, like jackhammers, are pneumatically powered. Others use hydraulic and electric power. The noise generated by these tools can range between 80 and 97 dB at 50 feet.

The noise generated by smaller, *general equipment*, such as small pumps and generators, is usually not as intense as that generated by the other equipment. Still, this noise must be taken into account when assessing the noise level of the work area as a whole.

NOISE CONTROL

In general, there are three basic ways to control noise:

1. At its source
2. Along its path
3. At the receiver.

Controlling noise at its source is probably the best approach. The reason is simple. If a piece of equip-

ment or a tool is operated at a safe noise level, there is no hearing danger posed and no need to use additional approaches to noise control.

Because source control is not always possible, the next best approach is to control the noise along its path. Such control limits the number of persons exposed to the noise. However, it does not always eliminate the noise problem for all persons affected, especially those working directly with or very near the noise source, and it often requires that new noise control steps be taken whenever equipment is moved or work sites are changed.

The use of ear protection equipment is not as desirable as either source control or path control. It affords protection only to those who are wearing the equipment. Further, certain conditions and activities can reduce the effectiveness of the hearing protectors themselves.

Source control begins with a careful analysis of the noise-producing equipment, to isolate the major sources of noise within the equipment and to determine how the noise is being transmitted from these sources. The major noise source may be an engine or a motor, but the noise itself may be transmitted as vibration by other parts of the equipment which, in turn, radiate the noise heard outside the equipment. In source control, both the primary and the secondary noise sources must be examined and quieted to the greatest extent possible.

The U.S. Environmental Protection Agency has outlined some specific applications of source control. Briefly, they include the following:

1. Reduce impact noise.
2. Reduce speed of moving and rotating parts.
3. Reduce pressure and flow velocities in circulating systems.
4. Balance rotating parts.
5. Reduce friction in rotating, sliding, and moving parts.
6. Reduce flow resistance in circulation systems.
7. Isolate vibration within equipment.
8. Reduce the size of the surface radiation and noise.
9. Apply vibration-damping materials to vibrating parts and surfaces.
10. Reduce the leakage of noise from within equipment.

These approaches to controlling noise at its source are simple and logical, and should constitute the first line of defense against noise produced by equipment and tools.

In situations where source control measures will not work or where such methods will not lower the

noise level to a safe point, control of noise along its path to the ear must be considered.

In *path control*, an attempt is made to block or reduce noise before it reaches the ears. The approach chosen depends on the type of equipment or tool and the working environment.

Reducing the leakage of noise from within equipment is a basic approach which applies both to source control and path control. Enclosing a noisy piece of equipment in a box or a room, or covering a noisy pipe with a heavy sound-absorbing material, can effectively reduce noise. Obviously, this may not be practical for highly mobile equipment. But for noisy equipment that is stationary or infrequently moved, it should be considered.

Absorbing noise is another approach common to both source control and path control. Sound-absorbing materials or acoustic lining in a box or room can be used to enclose equipment noise. Noise transmitted from its source through ducts, pipes, or electrical channels can be reduced through the use of sound-absorbing materials. The inside surfaces of these noise passageways can be lined with glass fiberboard, and the ducts, pipes, or channels can be wrapped with a glass fiber blanket. Baffles constructed of glass fiberboard can be installed inside the noise passageways. Unfortunately, due to the transient nature of the construction site, this approach is not always feasible.

Screens or barriers can be used to deflect the noise that is generated by equipment and tools. Much noise can literally be "walled-in" by barriers which surround the noise source. This can be aided by lining the barriers—which may be wood or metal panels—with sound-absorbing material.

But barriers do not have to surround the noise source to be effective in reducing noise transmission. If it is sufficiently large, a free-standing wall between the noise source and a worker can reflect much of the noise and create a noise "shadow" to protect the worker.

Putting distance between the noise source and the persons exposed to the noise is a simple and effective approach to path control. The further away from the noise source, the lower the noise level received.

Protective equipment. The need for personal hearing protection arises when source control and/or path control are either not feasible or inefficient. There are three basic types of personal protective hearing devices.

Materials such as fine glass wool, mineral fibers, and wax-impregnated cotton may be placed in the

ear. These must be replaced each day. Though such materials offer some level of hearing protection, they do not provide the same benefits as do other devices.

Ear plugs may be inserted in the ear. These must be individually fitted to the wearer.

Cup-type protectors—similar to ear muffs—may be worn with a head band or may be incorporated into safety helmets.

The amount of noise protection afforded by these devices varies from one device to another at different sound frequencies. Although it is difficult to generalize for all of the devices available commercially, the wearer of a hearing protection device may expect noise reduction ranging from 10 dB to over 40 dB at certain frequencies.

Noise levels encountered on the construction site

can and often does result in permanent hearing loss. If proper measures are taken to reduce the level of noise that reaches the worker's ear, the risk of such hearing loss can be greatly decreased.

References

1. American National Standards Institute Pamphlet No. N13.2.
2. Firenze, Robert J. and Walters, James B., *Safety and Health for Industrial/Vocational Education for Supervisors and Instructors* (Cincinnati: National Institute for Occupational Safety and Health, July 1981) Unit 13, "Health Hazards."
3. "Radiation and Radiation Protection," a pamphlet printed by the Boilermakers Local 169.
4. *Understanding Noise and Noise Control*, a publication of the Office of Noise Abatement and Control, U.S. Environmental Protection Agency (June, 1978), serves as the source for much of this section.

Instruction Key—Unit 16

Noise

Terms

1. Decibel (dB): a unit for measuring sound
2. Threshold of hearing: the sound level below which no sounds are heard
3. Temporary Threshold Shift (TTS): a condition in which the ability to hear sounds at lower decibel levels is temporarily lost
4. Permanent Threshold Shift (PTS): a condition in which the ability to hear sounds at lower decibel levels is permanently lost

Points for Discussion

1. Nature of sound
2. Process of hearing
3. Characteristics of sound
 - a. pitch
 - b. intensity
 - (1) decibels
 - (2) threshold of hearing
 - (3) Temporary Threshold Shift
 - (4) Permanent Threshold Shift
4. How noise damages hearing
 - a. sound level
 - b. duration of exposure
 - c. recovery periods
 - d. individual differences
5. Sources of noise on the work site
 - a. internal combustion engines
 - b. impact equipment
 - c. impact tools
 - d. general equipment
6. Noise control
 - a. at the source
 - b. along the path
 - c. at the receiver

Questions

1. At what noise level does the threshold of hearing normally occur?
2. What one condition can spell the difference between a temporary hearing loss and a permanent one?
3. What are some warning signals that a dangerous noise level has been reached?
4. At approximately what decibel level is hearing damage likely to occur?
5. Which is considered the most effective method of noise control? The least? Why?

Answers

1. It normally occurs near zero decibels, since the decibel scale was developed so that its zero point would coincide approximately with the threshold of hearing.
2. With the proper recovery time, the hearing threshold returns to normal. If the recovery time is insufficient, the hearing loss will remain permanently.
3. The three most common warning signals are a ringing in the ears, called "tinnitus," a threshold shift lasting more than a few hours, or a tickling sensation in the ears, which is actually a mild form of pain.
4. Decibel levels of eighty to ninety and above represent the beginning of potentially damaging levels of sound.
5. Controlling noise at the source is best because if a piece of equipment is operating at a safe noise level, there is no need for further control methods. Controlling noise at the receiver is the least effective. It protects only workers who are wearing protective devices. Further, certain conditions and activities can reduce the effectiveness of the hearing protectors themselves.

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UNIT 17

PERSONAL PROTECTIVE AND SAFETY EQUIPMENT AND SAFE PROCEDURES

Personal protective and safety equipment is to be used whenever the engineering controls (ventilation, cleaning, and enclosure or isolation of the hazard) cannot reduce the hazard to an acceptable level. Such equipment provides another level of protection and may be used even when the engineering controls alone seem sufficient. However, it is important to remember that personal protective equipment provides last-resort protection only.

The limitation of personal protective equipment is major: such equipment does nothing to reduce or eliminate the hazards. The equipment may also give the wearer a false sense of security. This means that, should a protective device become ineffective without the wearer's knowledge, he is exposed to a potentially dangerous situation.

SELECTING PERSONAL PROTECTIVE EQUIPMENT

Choosing the appropriate personal protective equipment is important. Making the proper choice should involve several criteria.

First, the extent of the hazard's potential for causing harm must be carefully evaluated. It is important to have a clear understanding of the nature of the hazard, where it originates, what harm it can cause, and the likelihood of its occurrence. For example, if a respirator is needed for protection from oxygen deficiency, the capabilities and limitations of various types of respirators must be understood. Without such a determination, a respirator could be selected that cannot perform the desired function.

Second, the degree of desired protection is in direct proportion to the seriousness of the hazard. Two dangers are present in selecting personal protective equipment: the danger of "overkill" and the danger of selecting equipment offering inadequate protection. For example, greater eye protection is required for welders than is necessary for workers assisting the welders. To offer the same device for both would mean either overprotection or underprotection, depending on the device selected.

The equipment's ability to interfere with the worker's performance on the job is a third factor to consider. Bulky gloves may decrease the dexterity required for certain tasks; full face shields may be cumbersome during certain operations. Sometimes the benefits of the most desirable alternative must be weighed against those of the most practical one before making the final selection.

A fourth factor to consider in selection is compliance with national standards. For most protective equipment (head, eye, face, and foot protection), a label showing compliance with the appropriate American National Standards Institute (ANSI) standard will be affixed to the product. In the case of respiratory equipment, the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA) have their label attached to the product. There are some types of protective equipment, such as gloves and aprons, for which no approvals are available.

Quality is a fifth factor to consider in selecting protective equipment. Although many manufacturers are selling equipment that meets the ANSI standards and NIOSH and MSHA approvals, their products are not all of the same quality. Given the constraint of cost, equipment of the highest quality should be purchased. A product of high quality will be easier to maintain and can be expected to have a longer service life.

Last but not least is the cost of the equipment. Good protective equipment is not inexpensive. The highest-quality equipment on the market normally costs proportionally more than its lower-quality counterpart. When a decision must be made to determine how much will be spent on protective equipment, it is important to determine how long the equipment will be needed. If it will be used for only a short period of time while more suitable control measures are being installed, less expensive equipment may serve the purpose. However, if the protective equipment is intended to serve its purpose indefinitely, allocating ample funds for acquir-

ing the highest-quality approved product should seriously be considered.

FACTORS INTERFERING WITH EFFECTIVENESS OF PERSONAL PROTECTIVE EQUIPMENT

Purchasing More Than One Type of Same Class

When more than one variety of the same class of protective device is used (for example, more than one brand of respirator), especially if each type has slightly different requirements for use, care, and maintenance, it becomes difficult to provide adequate maintenance, monitoring, and control. Ideally, one brand of a particular class of protective equipment should be used throughout the plant.

Insufficient or Improper Equipment Maintenance

If protective equipment is to continue providing protection, it requires care and maintenance. Cleaning and minor repairs are usually done by the workers or by maintenance personnel. More complex repairs or repairs designated to be done by the manufacturer should not be made by plant employees. In such instances, the equipment should be returned to the manufacturer or his designated service representative.

Improper Fit

Improperly protective equipment discourages worker acceptance and in some cases causes a loss of protection. For instance, protective eye wear that does not fit properly may end up in the worker's pocket, and a respirator facepiece that does not seal properly on the face will allow the toxic substance to enter the facepiece and be inhaled. When purchasing protective equipment, the need for proper fit should be considered. In cases where proper fit cannot be achieved with conventional equipment, special fitting devices may be necessary.

EYE PROTECTION

The protection of eyes from damage by physical and chemical agents has long been an essential part of a hazard control program. Some 140,000 disabling injuries occur annually, injuries that result in total or partial blindness.

In the confined workspace, the eyes are exposed to a variety of hazards: flying objects, splashes of corrosive liquids or molten metals, dust, and harmful radiation. OSHA requires that eye and face protection be designed to meet the performance requirements set forth in ANSI Z87.1, Practice for

Occupational and Educational Eye and Face Protection.

Contact Lenses

Both the National Society for the Prevention of Blindness and the American Optometric Association advise the use of contact lenses in industry only in conjunction with proper safety shields, goggles, or other protection. Two special precautions apply to wearers of contact lenses.

First, if caustic, chemical, or other solutions are accidentally splashed in the eye, the cornea may be burned. In the event of such an accident, first flush out the eye, then remove the lens, then flush the eye again.

Second, if a foreign body (dust, for example) gets under a contact lens, it may scratch the cornea. In the event of such an accident, the lens should be removed immediately. It may be necessary to consult a physician to make sure that the foreign body is no longer present.

HEARING PROTECTION EQUIPMENT

There are three basic types of personal hearing protection devices.

1. *Disposable pliable material*, such as fine glass wool, mineral fibers, and wax-impregnated cotton, may be inserted in the ear. It must be fresh each day.
2. *Ear plugs* may be inserted into the ear. They must be individually fitted to the wearer.
3. *Cup-type protectors*, similar to ear muffs, may be worn with the band over the head or around the back of the neck or may be incorporated into safety helmets.

BODY AND LEG PROTECTION

Where chemicals and caustics are present, special clothing should be used to protect various parts of the body as dictated by the exposure.

RESPIRATORY PROTECTION

During our discussion of health hazards in other units, we have examined the three modes of entry for hazardous materials: ingestion, skin absorption, and inhalation. The human respiratory system presents the quickest and most direct avenue of entry because it is intimately and inextricably connected with the circulatory system and the need to oxygenate tissue cells to sustain life processes.

When Respirators are Needed

The Occupational Safety and Health Administration (OSHA) and states working under an approved OSHA State Plan have established permissible

exposure limits (PELs) for many airborne toxic materials. OSHA Standards (29 CFR 1910.134) state:

In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used.

Respiratory protection is also required on several special occasions:

1. In oxygen-deficient atmospheres where the oxygen content in the breatheable air is insufficient;
2. For routine but infrequent operations in which persons are exposed briefly to high concentrations of a hazardous substance;
3. For non-routine operations involving similar exposure hazards.

Identifying and Evaluating Hazards

The hazard assessment should concentrate on locating four major categories of respiratory hazards:

1. Oxygen-deficient atmospheres
2. Gas and vapor contaminants
3. Particulate contaminants (including dust, fog, fume, mist, smoke, and spray)
4. Combinations of gas, vapor, and particulate contaminants.

It is important to determine the type(s) of contaminants likely to be present in the confined workspace in order to select intelligently the most effective respiratory equipment. Because each respirator is designed to provide protection for a certain contaminant or group of contaminants, an arbitrary choice of devices could place workers in a dangerous situation.

Selecting Respirators

Selection of the respirator should be based on:

1. The nature of the hazardous process or operation;
2. The type of respiratory hazard—
 - a. physical and chemical properties,
 - b. warning properties,

c. physiological and psychological effects on the body, and

d. concentration of the material;

3. The period of time for which respiratory protection must be provided;
4. The location of the hazard area in relation to the nearest source of uncontaminated respirable air;
5. The function and physical characteristics of respiratory protective devices.¹

The appendix following this unit illustrates a sample respiratory protective device selection guide.

CLASSES OF RESPIRATORS

The three major classes of respirators are:

1. Air-purifying respirators.
2. Supplied-air respirators.
3. Self-contained breathing devices.

Each class has various characteristics, advantages, limitations, and subcategories. Federal regulations applying to respiratory protective devices are contained in 30 CFR 1926.

Air-Purifying Respirators

Sometimes called, dust, mist, or fume respirators, air-purifying respirators by their filtering action remove contaminants from the atmosphere before they can be inhaled. Various chemicals can remove specific gases and vapors, and mechanical filters remove particulate matter.

There are four basic types of air-purifying devices:

1. Mechanical filter respirators;
2. Chemical cartridge respirators;
3. Combinations of chemical cartridge and mechanical filter respirators;
4. Gas masks.

Advantages

Air-purifying devices are small, relatively inexpensive, and easily maintained. Because of the various combinations of facepieces, mouthpieces, filters, cartridges, and canisters available, the devices can be tailored to suit specific situations.

Limitations

Air-purifying respirators *cannot be used in oxygen-deficient atmospheres* or where the air contaminant level exceeds the specified concentration limitation of the device. Seals on quarter-mask, half-mask, and mouthpiece respirators are not always reliable, nor do these respirators protect the eyes or skin.

Mechanical Filter Respirators

These offer protection against particulate matter, including dusts, mists, metal fumes, and smokes, but they do not provide protection against gases, vapors, or oxygen deficiency. They consist essentially of a facepiece (quarter mask, half mask or full-face) with a mechanical filter attached. Many kinds of mechanical respirators have filters specifically designed for the various classes of particulate matter.

Items to be considered in selecting mechanical respirators are:

1. The resistance to breathing offered by the filtering element;
2. The adaptation of the facepiece to faces of various sizes and shapes;
3. The efficiency in removing particulates of specific size ranges;
4. The time required to clog the filter.

Single-use dust. The single-use respirator is a respirator which is disposed of after use. Either the air purifier is permanently attached to the facepiece or the entire facepiece is made of filter material. At present, these respirators are approved only for pneumoconiosis- or fibrosis-producing dusts such as coal dust, silica dust, and asbestos.

Quarter-mask dust and mist and half-mask dust and mist. The quarter mask covers the mouth and nose, while the half mask fits over the nose and under the chin. The half mask produces a better facepiece-to-face seal than does the quarter mask and is therefore preferred for protection against more toxic materials.

Quarter-mask fume and half-mask fume. Quarter- and half-mask fume masks, similar to the quarter- and half-mask dust and mist masks, use a filter element which can remove metal fumes in addition to dusts and mists from the inhaled air.

Half-mask efficiency masks are the same as the respirators mentioned above but use a high efficiency filter. Because of this filter, they can be used against dusts, mists, fumes, or any combination thereof.

Full facepiece respirators cover the face from the hairline to below the chin. In addition to providing more protection to the face, the full facepiece respirators give a better seal than do the half- or quarter-mask respirators. Depending upon the type of filter used, these respirators provide protection against dusts, mists, fumes, or any combination of these contaminants.

Limitations of mechanical filter respirators. Air-purifying mechanical filter respirators offer no pro-

tection against atmospheres containing contaminant gases or vapors. They should not be used for abrasive blasting operations or in oxygen-deficient atmospheres. Another limitation is that the air flow resistance of a mechanical respirator filter element increases as the quantity of particles it retains increases, thus increasing breathing resistance.

Chemical Cartridge Respirators

Chemical cartridge respirators use various chemical filters to protect against certain gases and vapors. They differ from mechanical filter respirators in that they use cartridges containing chemicals to remove harmful gases and vapors. Consisting of a facepiece connected directly to one or two small canisters of chemicals, they offer protection against intermittent exposure to light concentrations (10 ppm to 1000 ppm by volume, depending upon the contaminant) of gases and vapors.

The cartridge, a chemical filtering element which attaches directly to the facepiece, is constructed as shown in Figure 17.1.

Uses. Many gases and vapors in extremely low concentrations may cause nausea and headache. Sometimes they may produce chronic disorders which eventually may be fatal. Chemical cartridge respirators are particularly useful for guarding against:

- Organic vapors (such as acetone, alcohol, benzene, carbon tetrachloride, gasoline).
- Acid gases (such as chlorine, sulfur dioxide).
- Other gaseous materials (such as ammonia gases, mercury vapor).

Limitations. Chemical cartridge respirators have their limitations. They should not be used against gaseous material that:

- Is extremely toxic in very small concentrations.
- Cannot be detected clearly by odor. Odor is necessary to alert the worker to the fact that the sorbent is saturated and that contaminated air is passing through the cartridge. Cartridges should be changed when the wearer smells the vapor.
- Is in concentrations which are highly irritating to the eyes, unless supplementary eye protection is used.
- Is not stopped effectively by the chemical fills (such as carbon monoxide) used.

Combination Mechanical Filter/Chemical Filter Respirator

The third category of air-purifying devices is the combination mechanical filter/chemical filter respi-

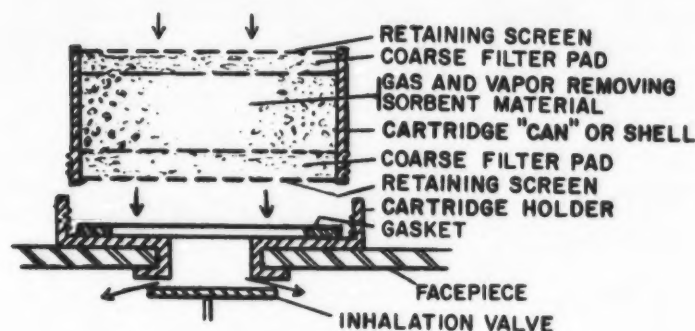


Figure 17.1. Typical Chemical Cartridge. Reprinted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976), p. 34.

rator, which uses a dust, mist, or fume filter with a chemical cartridge for dual or multiple exposure. Respirators with independently replaceable mechanical filters are sometimes used for this type of unit because the dust filter normally plugs before the chemical cartridge is exhausted.

One type of unit has a back-mounted filter element. It is especially well suited for spray painting and welding operations, where the air contaminant is concentrated in front of the worker.

Gas Masks

Gas masks consist of a facepiece connected by a flexible tube to a canister. Contaminated air is purified by chemicals in the canister. Gas masks offer respiratory protection against specific gases, vapors, and particulate matter. They are compact, economical, easy to operate, and easy to maintain. They are suitable for ventilating areas not subject to rapid change in air contaminant levels.

Types of Gas Masks

Various gas masks have been tested and approved by the U.S. Bureau of Mines for respiratory protection against specific gases and vapors specified on the label. OSHA regulations require that each gas mask canister be labeled and color-coded to indicate the type of protection afforded.

Chin-type canisters, because of their smaller size, should be limited to concentrations not in excess of .5 percent by volume. They may also be used against dust and mists.

The length of time that a gas mask provides protection depends upon:

- The type of canister.

- The concentration of contaminants in the air.
- The breathing rate of the user.
- The humidity.

Limitations

Gas masks are subject to the following limitations:

Their use must be restricted to atmospheres that contain sufficient oxygen to support life. Exposure concentrations must not exceed the specific limitations.

The masks should not be used against a gas or vapor with poor warning properties unless they have an indicator or timer that shows when the canister should be changed.

Supplied-Air Respirators

The second class of respirators delivers uncontaminated air through a supply hose connected to the wearer's facepiece. There are essentially two major groups of supplied-air respirators: the air line respirator and the hose mask with or without a blower.

Air Line Devices

Air line respirators use a stationary source of compressed air delivered through a high-pressure hose. A trap and filter are installed in the compressed air line ahead of the masks to separate oil, water, grit, or other matter from the airstream. Air line devices can be equipped with half- or full-face masks, helmets or hoods, or the devices can come as a complete suit. Air line respirators can be used for protection against particulates, gases, or vapors.

There are three basic classes of air line respirators.

The *constant flow* type has a regulated amount of air fed to the facepiece and is normally used where there is an ample air supply (such as that provided by an air compressor).

The *demand flow* type delivers air only during inhalation and is used where air supply is restricted to high-pressure compressed air cylinders.

The *positive pressure flow* type provides a positive pressure during both inhalation and exhalation, avoiding both the possible inward leakage caused by the negative pressure during inhalation which is part of the demand system and the relatively high air consumption of the constant flow system.

Limitations

Air line respirators cannot be used in atmospheres immediately dangerous to life or health because the user is completely dependent on the integrity of the air supply hose and the air source. If something happens to either the hose or air supply, the user cannot escape from the contaminated area without endangering his life. Extreme care must be taken to ensure that the source of air is free of hazardous substances such as carbon monoxide and oil mist.

Compressors or similar devices must be situated to avoid entry of contaminated air into the system. Alarms must be installed on compressors to indicate compressor failure and overheating, as well as excessive levels of carbon monoxide.

Air line hose must never exceed 300 feet in length. This requirement limits the wearer to a fixed distance from the air supply source. The hose must be protected from objects that could cut or puncture it during use. Connections on the air line must be airtight.

Hose Masks

Hose masks supply outside air to the wearer through a length of hose. They are available either without a blower or with a power-driven or hand-operated blower.

Masks with blowers. NIOSH and MSHA have approved hose masks with blowers for respiratory protection in any atmosphere—regardless of the degree of contamination or oxygen deficiency—if clean, breathable air can be reached within the distance of the permissible hose length (up to 300 feet), and if there is a person standing by with suitable rescue equipment.

The air hose must have a large inside diameter (approximately one inch) so that, in case of blower failure, the wearer can breathe through the hose

while escaping from the contaminated area. The hose must be able to withstand crushing weight and be highly resistant to petroleum vapors.

Hose masks without blowers are used when uncontaminated air can be reached within seventy-five feet. Such units carry only limited approval and cannot be used in atmospheres immediately dangerous to life and health.

Self-Contained Breathing Apparatus (SCBA)

Self-contained breathing apparatus (SCBA), the third class of respirator, provides complete respiratory protection against toxic gases and oxygen deficiency. The SCBA allows the user to carry a respirable breathing supply and eliminates the need for a stationary air source to provide breathable air. The wearer is independent of the surrounding atmosphere because he is breathing with a system admitting no outside air. This allows comparatively free movement over an unlimited area.

In an environment that contains a substance that is dangerously irritant or corrosive to the skin, a self-contained breathing apparatus must be supplemented by protective clothing.

Types

There are four basic types of SCBAs: oxygen cylinder rebreathing, self-generating, demand, and positive pressure. The first two are *closed circuit*; the second two are *open circuit* systems.

In the *closed circuit* devices, air is rebreathed after the exhaled carbon dioxide has been removed and the oxygen content restored. These devices are designed primarily for one- to four-hour use.

Oxygen cylinder rebreathing. This type consists of a relatively small cylinder of compressed oxygen, reducing and regulating valve, a breathing bag, facepiece or mouthpiece plus noseclip, and a chemical container to remove carbon dioxide from the exhaled breath.

The *self-generating* type uses the principle of rebreathing, but it has no mechanical operating components. It has a chemical canister that evolves oxygen and removes the exhaled carbon dioxide. The wearer, using the canister, makes his own oxygen instead of drawing it from a compressed gas cylinder or liquid oxygen source.

Open circuit devices have an air supply which lasts from three to thirty minutes, depending on the respirator. When compared with rebreathing types, they are relatively inefficient because the exhaled air, which is still rich in oxygen, is released into the atmosphere instead of being used again.

Demand. All the different models of demand type apparatus designed for specific applications consist of a high-pressure air cylinder, a demand regulator connected either directly or by a high-pressure tube to the cylinder, a facepiece and tube assembly with exhalation valve or valve, and a method of mounting the apparatus on the body. After putting in the facepiece, the wearer opens the cylinder valve. The airflow is automatically regulated to the desired level to accommodate for varying breathing needs. The exhaled air passes through a valve in the facepiece to the surrounding atmosphere.

Positive pressure apparatus uses the same principle as positive pressure air line respirators. They are used in the same circumstances; namely, where the toxicity is such that the potential facepiece leakage of demand apparatus presents an intolerable hazard.

Medical Aspects of Using Respiratory Equipment

The use of any type of respirator may impose some physiological stress on the user. Air-purifying respirators, for example, make inhaling more difficult because the filter or cartridge impedes the flow of air; exhaling is more difficult because the expired air must force open a valve. The special exhalation valve on an open circuit pressure-demand respirator requires the wearer to exhale against significant resistance. The bulk and weight of an SCBA—up to thirty-five pounds—can be a burden. Someone using an air line respirator or hose mask may have to drag around up to 300 feet of hose.

All of the above factors can increase significantly the user's workload. Those requiring respiratory equipment should have a medical examination to determine whether they have sufficient cardiovascular and pulmonary fitness to accommodate the additional physiological stress.

Maintaining Respirators

In large programs where respiratory protective equipment is used routinely, respirators should be cleaned and disinfected daily. In small programs where respirators are used only occasionally, weekly or monthly cleaning and disinfecting are appropriate. Individual users who maintain their own respirators should be trained in the cleaning of respirators. The following suggestions are adapted from *A Guide to Industrial Respiratory Protection* (Cincinnati: NIOSH, 1976).

Methods of Cleaning

Two methods of cleaning can be adapted to the confined workspace safety and health program.

The respiratory protection equipment may be washed with detergent in warm water, using a brush, thoroughly rinsed in clean water, and then air-dried in a clean place. Care should be taken to prevent damage from rough handling. This method is an accepted procedure for a small respirator program or a program where each user cleans his own respirator.

Or, a standard domestic-type clothes washer may be used if a rack is installed to hold the facepieces in a fixed position. (If loose facepieces are placed in a washer, the agitator may damage them.) This method is especially useful in large programs where respirator usage is extensive.

If possible, detergents containing a bactericide should be used. Organic solvents should not be used because they can deteriorate the rubber facepiece. If a detergent containing a bactericide is not available, a regular detergent may be used, followed by a disinfecting rinse. Reliable disinfectants may be made from some available household solutions.

Hypochlorite solution (50 ppm of chlorine) can be made by adding approximately two tablespoons of chlorine bleach per gallon of water. A two-minute immersion disinfects the respirators.

Aqueous solution of iodine (50 ppm) can be made by adding approximately one teaspoon of tincture of iodine per gallon of water. A two-minute immersion is sufficient and will not damage the rubber and plastic in the respirator facepiece.

Check with the manufacturer to find out the proper temperature for the solution.

If the respirators are washed by hand, a separate disinfecting rinse may be provided. If a washing machine is used, the disinfectant must be added to the rinse cycle, and the amount of water in the machine at that time will have to be measured to determine the correct amount of disinfectant to be added.

The cleaned and disinfected respirators should be rinsed thoroughly in clean water (140°F maximum) to remove all traces of detergent, cleaner, sanitizer, and disinfectant. This is very important to prevent dermatitis.

The respirators may be allowed to dry by themselves on a clean surface. They may also be hung from a horizontal wire, like drying clothes, but care must be taken not to damage the facepieces.

Storage

All the care that has gone into cleaning and maintaining a respirator can be negated by improper storage. Respiratory protective equipment must be stored so as to protect it from dust, sunlight, heat, extreme cold, excessive moisture, and damaging chemicals. Leaving a respirator unprotected—on a workbench or in a tool cabinet or tool box among heavy wrenches—can lead to damage of the working parts or permanent distortion of the facepiece, making the respirator ineffective.

After the respirators are cleaned and disinfected, they should be placed individually in heat-sealed or reusable plastic bags until re-issue. They should be stored in a single layer with the facepiece and exhalation valve in a more or less normal position to prevent the rubber or plastic from taking a permanently distorted "set."

Inspection

An important part of a respirator maintenance program is the inspection of the devices. If carefully performed, inspections will identify damaged or malfunctioning respirators. All respiratory protective equipment must be inspected before and after each use, and during cleaning. Equipment designated for emergency use must be inspected after each use, during cleaning, and at least monthly. Self-contained breathing apparatus must be inspected at least monthly.

Recordkeeping. A record must be kept of inspection dates and findings for respirators maintained for emergency use.

Correcting Defects²

The following section itemizes some primary defects to look for when inspecting respirators. Information within the parentheses suggests appropriate action to be taken when defects are discovered.

1. Air-purifying respirators (mechanical filter, chemical cartridge, combination mechanical filter/chemical cartridge, gas mask)

a. Rubber facepiece—check for:

- excessive dirt (clean all dirt from facepiece);
- cracks, tears, or holes (obtain new facepiece);
- distortion (allow facepiece to "sit" free from any constraints and see if distortion disappears; if not, obtain new facepiece);
- inflexibility (stretch and massage to restore flexibility);

- cracked, scratched, or loose fitting lenses (contact respirator manufacturer to see if replacement is possible; otherwise, obtain new facepiece).

b. Headstraps—check for:

- breaks or tears (replace headstraps);
- loss of elasticity (replace headstrap);
- broken or malfunctioning buckles or attachments (obtain new buckles);
- excessively worn serrations on the head harness which might allow the facepiece to slip (replace headstrap).

c. Inhalation and exhalation valves—check for:

- detergent residue, dust particles, human hair, or dirt on valve or valve seat (clean residue with soap and water);
- improper insertion of the valve body in the facepiece or improper installation of the valve in the valve body (correct insertion and installation);
- cracks, tears, or distortion in the valve material or valve body (contact manufacturer for instructions);
- missing or defective valve cover (obtain valve cover from manufacturer).

d. Filter element(s)—check for:

- proper filter for the hazard;
- approval designation;
- missing or worn gaskets (contact manufacturer for replacement);
- worn threads, both filter threads and facepiece threads (replace filter or facepiece, whichever is applicable);
- cracks or dents in filter housing (replace filter);
- deterioration of gas mask canister harness (replace harness);
- service life indicator or end of service date; or, in the case of a gas mask, expiration (contact manufacturer to find out if your filter element has one; if not, ask what will indicate the "end of service").

e. Corrugated breathing tube (gas mask)—check for:

- cracks or holes (replace tube);
- missing or loose hose clamps (obtain new clamps);
- broken or missing end connectors (obtain new connectors).

2. Supplied-air respirators

a. Check facepiece, headstraps, valves, and

- breathing tube as for air-purifying respirators (l. a-c and e above).
- b. Hood helmet, blouse, or full suit—check for:
 - rips and torn seams (if unable to repair the tear adequately, replace);
 - headgear suspension (adjust for individual fit);
 - cracks or breaks in faceshield (replace faceshield);
 - intact protective screen, which fits correctly over the faceshield of abrasive blasting hoods and blouses (obtain new screen).
- c. Air supply systems—check for:
 - breathing air quality;
 - breaks or kinks in air supply hoses and end-fitting attachments (replace hose and/or fitting);
 - tightness of connections;
 - proper setting of regulators and valves (consult manufacturer's recommendations);
 - correct operation of air-purifying elements and carbon monoxide or high-temperature alarms.
- 3. Self-contained breathing apparatus—consult manufacturer's literature.

Fitting the Respirator to the Wearer

It is essential that respiratory protective equipment be properly fitted to the user. All the care that went into the design and manufacture of a respirator to maximize protection will be lost if there is an improper match between facepiece and wearer. Fitting tests should be repeated at appropriate intervals, particularly when there is a change in the wearer's physical state, such as growth of facial hair or change in facial contours.

Facial hair lying between the sealing surface of a respirator facepiece and the wearer's skin will prevent satisfactory sealing. The sealing problem is especially critical when non-powered air-purifying respirators are used. The negative pressure developed in the facepiece of these respirators during inhalation can lead to leakage of the contaminant into the facepiece when there is a poor seal. Some supplied-air respirators of the air line type, because of their mode of operation, can also lead to leakage at the sealing surface. Therefore, individuals who have stubble (even a few day's growth), a moustache, sideburns, or a beard that passes between the skin and the sealing surface should not wear a respirator.

Corrective lenses that have temple bars or straps should not be used when a full-facepiece respirator is worn since the bars or straps could pass through the facepiece-to-face seal. Manufacturers of respiratory equipment can provide kits for installing eyeglasses in their respiratory facepieces. These glasses or lenses must be mounted by a qualified individual to ensure proper fit.

Contact lenses—According to OSHA regulations (29 CFR 1910.134), the "wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed." A properly fitted respirator (primarily a full-facepiece respirator) may stretch the skin around the eyes, thus increasing the possibility that the contact lens will fall out. Furthermore, contaminants that do penetrate the respirator may go underneath the contact lens and cause severe discomfort. The user's first reaction—to remove the facepiece to remedy the situation—could be fatal in a lethal environment.

Miscellaneous sealing problems—Scars, hollow temples, very prominent cheekbones, deep skin creases, and lack of teeth or dentures may cause respiratory facepiece sealing problems. Dentures or missing teeth may cause problems when sealing a mouthpiece in a person's mouth. Full dentures should be retained when wearing a respirator, but partial dentures may or may not have to be removed, depending upon the possibility of swallowing them. With full lower dentures, problems in fitting quarter-masks can be expected, as the lower part of the mask tends to unseat the denture.

LIFE LINES AND HARNESSES

Where exposure in the confined space may be acute or may require an employee to wear respiratory protection, or where rescue may be difficult, a body harness with a life line attached must be worn. Such equipment is to be used when the shape, size, and location of the confined space permits the safe emergency removal of the workers by standby personnel without requiring entry into the confined space.

An additional life line must be available for each person within the confined space. Should an attached life line become fouled to such an extent that attempting to free the line would be time consuming and dangerous, the life line will be detached and a new one hooked on to effect a rescue.

It is often advisable to have a block and tackle positioned on a tripod or otherwise fastened above the manhole. When a confined space means of egress is limited in size, the free end of the lifeline

should be secured to a fixed object and must be attended by a standby assistant.

The life line should be installed at a point over the head height and must be able to withstand a weight of 5400 pounds as per OSHA requirements.

OSHA requirements further state:

Lifelines, safety belts, and lanyards shall be used only for employee safeguarding. Any lifeline, safety belt, or lanyard actually subjected to in-service loading, as distinguished from static load testing, shall be immediately removed from service and shall not be used again for employee safeguarding.

Safety belt lanyard is required to be a minimum of 1/2-inch nylon or equivalent. Maximum length of fall should be no greater than six feet.

All safety belt and lanyard hardware is to be drop forged or pressed steel, cadmium plated. The surface must be smooth and free of sharp edges.

Before this equipment is used in an actual work situation, a practice run should be carried out in order to familiarize the workers with its proper use.

To test before use, pull hard on the cable and maintain the tension after it has locked securely. To unlock relieve the cable tension.

Maintenance. Visual inspection should be performed at least every three months. The life line system must be given regular visual inspection to determine whether any of the parts have changed appearance, have been damaged, or may require maintenance or reconditioning. The system must always be returned to the factory if there is any doubt as to whether the system should be retired from service after a fall has occurred in order to meet OSHA requirements.

COMMUNICATIONS

Communications must be maintained at all times between personnel within the confined space and personnel outside the space. This may be accomplished by one or a combination of the following methods:

1. Visually, by an assistant outside the area.
2. Vocally, by an assistant outside the area.
3. By telephone (hard wire).
4. By electronic radio transmitter, using FM radios.

A clearly understandable signal system should be established before the entry into the confined space in the event of failure of the above means of communication. This alternative signal system uses line-jerk signals in the following manner:

- One pull—allow more slack in the line.
- Two pulls—lead line is inadequate.
- Three pulls—emergency, pull man from confined space.

Other forms of communication may be used, as well. For instance, a loud horn may be used in large confined spaces where the workers may be some distance from the access openings. Verbal communication may be used where the space is relatively small and background noise would not mask a call for help. A Claxon horn or phone connection should be used to call for additional rescue and medical assistance.

If none of these means of communications is available, no entry should be made into the confined space.

BUDDY SYSTEM

Any time anyone is working inside a confined space, someone else should be stationed outside the space to function as an assistant, or "buddy." This buddy will observe the work inside the confined space from the outside. The buddy should be equipped with the necessary safety equipment and should be aware of the conditions of personnel within the confined space at all times. The buddy may pass tools, but he must have no other job which will take his attention away from the men in the confined space and/or which will interfere with his attempts to withdraw the victim by use of the life line, or which will require his leaving the vicinity of the confined space for any length of time. The number of men within a confined space at any given time must be kept to the minimum required to perform the work.

In the event of an emergency, the buddy must never enter the confined space until he is relieved at this post. It is his job to summon aid immediately, to attempt to remove the victim by use of the life line, and to perform all other necessary rescue functions from outside. Assistance for effecting a rescue should be readily available. The buddy may enter the confined space for rescue work only when he is assured that adequate outside assistance is present. Immediately-available site personnel must be well trained in basic first aid, rescue breathing techniques, and CPR.

At least one unit of self-contained breathing equipment or equivalent air line equipment must be located outside and convenient to the confined space along with a harness, rope, and other such emergency equipment as may be necessary.

SUMMARY

Personal protective equipment is no substitute for engineering controls. As a supplement to safe work practices, however, personal protective equipment provides safeguards against common hazards: flying particles, molten metal, chemical exposure, splashing liquids, excessive noise, sharp objects, etc. If operations and processes are to take place in an environment where hazards have been evaluated and are being controlled, equipment must be selected wisely, maintained properly, and used carefully.

Notes

1. Adapted from *Fundamentals of Industrial*

Hygiene, 2nd ed. (Chicago: National Safety Council, 1979), p. 717.

2. This section is adapted from *Respiratory Protection: Employer's Manual* (Cincinnati: NIOSH, 1978), pp. 20-22.

References

1. "Confined Space Entry Procedures for Operating Facility Projects," a company information pamphlet distributed by Brown and Root.
2. Evalok 50 Personal Lifeline and Ladder Safety Device, instruction pamphlet, copyright 1979, Research and Trading Corporation Form #552.
3. *Safety and Health for Industrial/Vocational Education* (Cincinnati: NIOSH) July 1981. Unit 14, "Personal Protective Equipment."

Instruction Key—Unit 17

Safety Equipment and Safe Procedures

Points for Discussion

1. Selecting personal protective equipment
 - a. Extent of the hazard
 - b. Degree of desired protection
 - c. Equipment's ability to interfere with work performance
 - d. Compliance with national standards
 - e. Quality
 - f. Cost
2. Factors interfering with effectiveness of personal protective equipment
 - a. Purchasing more than one type of same class
 - b. Insufficient or improper equipment maintenance
 - c. Improper fit
3. Eye protection
4. Hearing protection equipment
 - a. Disposable pliable material
 - b. Ear plugs
 - c. Cup-type protectors
5. Respiratory protection
 - a. When respirators are needed
 - b. Identifying and evaluating hazards
 - c. Selecting respirators
6. Classes of respirators
 - a. Air-purifying respirators
 - 1) advantages
 - 2) limitations
 - 3) mechanical filter respirators
 - 4) chemical cartridge respirators
 - 5) combination mechanical filter/chemical filter respirator
 - 6) gas masks
 - b. Supplied-air respirators
 - 1) air line devices
 - a) constant flow
 - b) demand flow
 - c) positive pressure flow
 - d) limitations
 - 2) hose masks
 - a) masks with blowers
 - b) masks without blowers

- 3) self-contained breathing apparatus (SCBA)
 - a) oxygen cylinder rebreathing
 - b) self-generating
 - c) open circuit
 - d) demand
 - e) positive pressure
- c. Medical aspects of using respiratory equipment
- d. Maintaining respirators
 - 1) methods of cleaning
 - 2) storage
 - 3) inspection
- e. Fitting the respirator to the wearer
7. Life lines
8. Communications
9. Buddy system

Questions

1. What is the major limitation of personal protective equipment?
2. What are some factors that reduce the effectiveness of personal protective equipment?
3. Why is respiratory protection so important when working in confined workspaces?
4. What is the most complete form of respiratory protection?

Answers

1. The limitation is twofold. First, it does nothing to reduce or eliminate the hazards. Second, it may lend a false sense of security. This means that, if the protective device becomes ineffective without the wearer's knowledge, he is exposed immediately to the hazard.
2. Purchasing more than one type of the same class of equipment, insufficient or improper equipment maintenance, and improper fit will all reduce the effectiveness of protective equipment.
3. The respiratory system is the most direct avenue of entry of toxic substances.
4. The self-contained breathing apparatus provides the most complete respiratory protection.

Appendix
RECOMMENDED RESPIRATORY SELECTION GUIDE

Appendix
RECOMMENDED RESPIRATORY SELECTION GUIDE

Hazard	Concentration* Less Than or Equal To	Respirator†
particulate	5 x PEL	single use respirator‡
particulate	10 x PEL	any dust respirator‡
particulate	50 x PEL	full facepiece respirator with high efficiency filter(s) or self-contained breathing apparatus with full facepiece operated in the demand mode
particulate	2000 x PEL	supplied-air respirator with full facepiece operated in any positive pressure mode
particulate	greater than 2000 x PEL	self-contained breathing apparatus with full facepiece operated in the pressure demand mode or a supplied-air respirator with full facepiece operated in any positive pressure mode with an auxiliary self-contained breathing apparatus
known gas or vapor contaminant§	50 x PEL	chemical cartridge respirator with full facepiece and cartridges approved for the specific contaminant(s) or a full facepiece self-contained breathing apparatus operated in the demand mode
known gas or vapor contaminant‡	2000 x PEL	supplied-air respirator with full facepiece operated in any positive pressure mode
	greater than 2000 x PEL	self-contained breathing apparatus with full facepiece operated in the pressure-demand mode or combination supplied-air respirator with full facepiece operated in any positive pressure mode with an auxiliary self-contained breathing apparatus
combination of particulates and gases or vapors§	50 x PEL	a full facepiece combination respirator approved for dusts and mists and the specific contaminant(s) (gases or vapors)

Personal Protective and Safety Equipment and Safe Procedures

Hazard	Concentration* Less Than or Equal To	Respirator†
	1000 x PEL	powered air-purifying full facepiece combination respirator with high efficiency filter and chemical cartridge approved for the specific gas or vapor
	2000 x PEL	supplied-air respirator with full facepiece operated in any positive pressure mode
	greater than 2000 x PEL	self contained breathing apparatus with full facepiece operated in the pressure-demand mode or combination supplied-air respirator with full facepiece operated in any positive pressure mode with an auxiliary self-contained breathing apparatus
unknown contaminant	undetermined	self-contained breathing apparatus with full facepiece operated in the positive pressure mode or a supplied-air respirator with full facepiece operated in any positive pressure mode with an auxiliary self-contained breathing apparatus
inert and other atmospheres where the oxygen level is below 17%		self-contained breathing apparatus with full facepiece operated in the pressure demand mode or a combination supplied air respirator with full facepiece operated in any positive pressure mode with an auxiliary self-contained breathing apparatus
emergency entry	unknown	self-contained breathing apparatus with full facepiece operated in the pressure demand mode or a combination supplied-air respirator with full facepiece operated in any positive pressure mode with an auxiliary self-contained breathing apparatus

*If the concentration forms a flammable atmosphere only the self-contained breathing apparatus with full facepiece operated in the pressure-demand mode may be used.

†Any respirator recommended for a higher concentration may be used at a lower concentration.

‡These respirators may not be used if the toxic material is carcinogenic.

§If the concentration forms an atmosphere which is immediately dangerous to life then only the self-contained breathing apparatus operated in the pressure mode or the combination supplied-air respirator with full facepiece operated in any positive mode with an auxiliary self-contained breathing apparatus may be used.